PEAK SHIFT AND INHIBITORY STIMULUS CONTROL

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ABSTRACT

Pigeons were exposed to discrimination training procedures using one-key multiple schedules of reinforcement and to generalization testing along dimensions of the two training stimuli. In the first two experiments using intradimensional discrimination training, both extinction and signalled reinforcement suppressed key-peck rate in one component and produced positive behavioural contrast, but only the extinction-trained group showed peak shift. Interdimensional training was used in the next four experiments and again the effects of stimulus control were compared. Both procedures resulted in excitatory dimensional stimulus control around the stimulus associated with the unchanged component but only the extinction procedure resulted in inhibitory dimensional stimulus control around the conditioned inhibitory stimulus, during generalization testing in extinction. Dimensional stimulus control was also investigated using two further types of generalization test, viz. combined-cue and resistance-to-reinforcement. However, these did not in general add anything to the analysis based on generalization testing in extinction. The results were discussed in the light of Spence's theory of gradient summation, which they supported, and Terrace's account of the by-products of discrimination learning, which they did not.

CHAPTER 1

INTRODUCTION

1. STIMULUS CONTROL

> "Stimulus control refers to the extent to which the value of an antecedent stimulus determines the probability of occurrence of a conditioned response."

This definition of stimulus control given by Terrace (1966a, p.271) describes an area of investigation in which much experimental and theoretical work has been conducted, particularly in the last twenty years, in attempts to elucidate the factors influencing changes in behaviour resulting from changes in the stimulus conditions, within an operant learning paradigm. The area of study implied in stimulus control is the discriminative function of a stimulus with respect to a response. The function of a discriminative stimulus in an operant paradigm is to indicate to the organism whether or not reinforcement will follow a response, or what schedule of reinforcement is currently in effect. Nowhere does Terrace define the stimulus referred to, but within the tradition of the analysis of operant behaviour, both stimuli and responses are given operational definitions. Stimulus control of responding therefore occurs when a change in a stimulus is followed by a change in responding, typically, by a change in response rate. Stimuli differ from each other in innumerable ways. Each stimulus, no matter how apparently simple, is made up of several elements. Each such element can be systematically changed while all the other elements are held constant. The continuum along which this change is conducted is one of the dimensions on which the stimulus lies. Because the stimulus is made up of several elements, it must lie concurrently at some point along several dimensions. The observed change in performance that occurs when the stimulus is changed along one, and only one, of the dimensions on which it lies, gives a measure of dimensional stimulus control.

There are a number of different training procedures which all produce different response rates in the presence of the training stimuli, thereby establishing stimulus control. These discrimination training procedures differ not only in the number and type of stimulus used, but also in the way they are presented. In simultaneous discrimination training, the training stimuli are present at the same time but at different loci. Usually these loci are alternated intermittently so that it is not the location of the stimuli that exerts control over responding. During successive discrimination training, however, only one of the training stimuli is present at one time. Usually all the training stimuli are presented at a single locus, for several predetermined periods of time, and alternated intermittently so that the order of their presentation does not control responding.

Discrimination training refers to one or the other of the above procedures and usually only two training stimuli are used.

Discrimination training procedures can also be defined in terms of the relationship between the two training stimuli. Switalski, Lyons and Thomas (1966) distinguished between intra- and interdimensional training. Intradimensional training refers to the procedure used when the two stimuli are selected from the same dimension, and interdimensional training to the situation where S1 and S2 are orthogonal with respect to the particular dimension under consideration. In studies of stimulus control, much work has been done using multiple schedules as the discrimination training procedure. In two-component multiple schedules, one schedule is correlated with one of the training stimuli, and a second independent schedule is correlated with the other. Although the two components of a multiple schedule comprise independent reinforcement schedules and separate exteroceptive stimuli, the performance of the subject in one of these components is not the same as it would be if training involved that same schedule and stimulus alone. There are interactions between the behaviours controlled by each component. One such interaction that occurs in successive discrimination training is positive behavioural contrast, first systematically studied by Reynolds (1961) although the phenomenon had been previously reported (Skinner, 1938).

It is of interest in the context of stimulus control because it is counterintuitive: the subject works harder, i.e. responds at a higher rate, for the same amount of reinforcement as it had received prior to discrimination training. It is an instance where the effect of a manipulation on one behaviour is not independent from the other.

Definitions of contrast effects usually refer to the change in response rates in both components of a multiple schedule following a change in one of the two schedules. If the response rate in the unchanged component increases and the rate in the changed component decreases, this is called positive behavioural contrast. The opposite occurrence, i.e. a decreased response rate in the unchanged component and an increased response rate in the changed component, is called negative behavioural contrast. Positive induction refers to an increase in response rate in both components, and negative induction to a decrease in both (Skinner, 1938).

However, more recently the terms "positive contrast" or "positive behavioural contrast" have been used when referring to the response rate in the unchanged component only. Bloomfield (1969) thus refers to positive behavioural contrast if there is an increase in the rate of reinforced responding during one component when the consequence of responding in another component is changed from reinforcement to extinction. Negative contrast and both positive and negative induction could also be similarly defined in terms of response rate changes in the component where the reinforcement schedule was not altered. The advantage of defining such effects solely in terms of the response rate in the unchanged component, without reference to response rate changes in the other components, is that it acknowledges interactions between the components yet enables these to be investigated independently. Using Bloomfield's approach, if positive behavioural contrast is said to have occurred, this implies that the changed component has affected responding in the unchanged component. It does not imply the reverse, that the unchanged component has affected the response rate in the changed component. Nor does the occurrence, or rather, labelling of a contrast effect, depend upon the occurrence or magnitude of response rate changes in the changed component. Following discrimination training to some criterion of stimulus control, a generalization test can be conducted for evidence of dimensional stimulus control. Generalization gradients have been plotted along many stimulus dimensions, following Pavlov's (1927) demonstration that the effectiveness of a new stimulus in eliciting a conditioned response was less the further away this stimulus was from the original conditioned stimulus, along some dimension of those stimuli.

The kind of dimensional stimulus control observed during such testing along a dimension depends upon the relationship between the two training stimuli. Following intradimensional discrimination training, the subsequent generalization gradient reflects the interaction between the two training stimuli. After interdimensional training, generalization gradients can be obtained which show dimensional stimulus control around one of the training stimuli, independently of the dimensional control around the other. The methods of generalization testing will be discussed later.

When the post-discrimination training generalization test is conducted along some dimension common to both training stimuli, then that discrimination training was intradimensional with respect to the test dimension. In conventional discrimination learning terminology, these discriminative stimuli associated with each component of the multiple schedule are usually referred as S+, the positive stimulus, and S-, the negative stimulus. Usually, S+ refers to the stimulus of the unchanged component, and S- to the stimulus of the changed component. However, such terminology may not be appropriate when the stimuli involved are correlated with schedules or events other than reinforcement versus extinction. Therefore throughout this study, the terms S1 and S2 are used to replace S+ and S- respectively. S1 thus refers to the stimulus associated with the component where the schedule remains unchanged throughout baseline and discrimination training and S2 refers to the stimulus associated with the component where the reinforcement schedule is altered during discriminative training.

Following intradimensional training, the obtained generalization gradient often shows peak shift, i.e. the maximum response rate occurs in the presence of a stimulus displaced from S1 in a direction away from S2. The converse of this may also be observed, viz. the displacement of the minimum rate of responding away from S2 in a direction opposite S1. This is often referred to as negative peak shift.

The following sections will deal in more detail with the phenomena related to stimulus control that have been discussed so far. No attempt is made to provide comprehensive reviews here of the areas discussed, as there are appropriate reviews already published which fulfil this purpose. Instead, the discussion is aimed at providing the context in which the current series of experiments is placed.

(i) Positive behavioural contrast

Reynolds' (1961) procedure has provided a paradigm adopted by later researchers investigating positive behavioural contrast. He first gave nondifferential reinforcement in two components of a multiple schedule in a successive discrimination where responses in each component were reinforced on a variable interval of three minutes, i.e. a *mult* VI-3min VI-3min schedule. He then changed the schedule operating in one component to extinction, i.e. to *mult* VI-3min EXT. The response rate in the changed component decreased now that no responses were reinforced in that component, but there was also an increase in the response rate in the unchanged component. This increase, i.e. positive behavioural contrast, is also observed when the initial baseline phase is not a multiple schedule with equal schedules in both components, but involves a single schedule. This is known as single-stimulus training (Terrace, 1966b).

Contrast is a robust phenomenon that has been reported in several species, particularly pigeons (e.g. Reynolds, 1961), but also in turtles (Pert and Gonzalez, 1974), rats (Guttman, Sutterer and Brush, 1975), humans (O'Brien, 1968; Nicholson and Gray, 1972), and goldfish (Pert and Gonzalez, 1974). It has also occurred not only when the schedule in the changed component is extinction (e.g. Reynolds, 1961), but also when this component is correlated with the differential reinforcement of low response rates (DRL) (e.g. Bloomfield, 1967; Terrace, 1968; Weisman, 1969); a lower variable-interval schedule (VI) (e.g. Thomas and Cameron, 1974); differential reinforcement of other behaviours (DRO) (e.g. Reynolds and Catania, 1961; Weisman, 1970); delayed reinforcement (e.g. Keller, 1970; Richards, 1972; Wilkie, 1971; Wilkie, 1972); punished responding (Brethower and Reynolds, 1972; Coates, 1972; Terrace, 1978) and a reduced quality of reinforcement (Griffin and Cooper, 1971).

Much work has been reported on attempts at establishing the necessary and sufficient conditions for its occurrence. Smith and Hoy (1954) hypothesised that an animal emits a stable number of responses and that behavioural contrast keeps this constant. When the response rate decreases in one component, the subject must respond at a higher rate elsewhere (i.e. in the other component) in order to maintain a constant response output.

Another analysis is known as the "additivity theory", put forward by Gamzu and Schwartz (1973), Keller (1974), and Ricci (1973), who propose that elicited pecking such as that which occurs during autoshaping (Williams and Williams, 1969), accounts for the additional key pecks pigeons emit in the unchanged component during positive behavioural contrast. Keller developed the use of Catania's (1973) "topographic tagging" technique, which separates out two response classes that were previously indistinguishable because they occurred to the same key, even though they were controlled by different variables. Keller separated elicited and operant key pecks by displacing the component stimuli away from the operant key, on to a second key. Operant key pecks were reinforced according to the schedule in effect during that particular component, but pecks to the second key were never reinforced. It was assumed that pecks to the first key reflected those controlled by the response-reinforcer relation but pecks to the second key were determined by the stimulus-reinforcer relation. Using this procedure, Keller demonstrated local positive behaviour contrast on the second key (called the signal key) but not in responding to the operant key. White and Thomas (1979) took this investigation further by looking at the dimensional stimulus control of responding to both keys. Using a generalization testing procedure that maintained higher rates of signal-key responding than would otherwise occur, they demonstrated reliable dimensional stimulus control over signal-key pecking as well as over operant-key pecking. Peak shift also occurred for signal-key responding but not for operant-key responding.

The additivity theory of behavioural contrast does however appear limited to explanations of a specific response (key-pecking) in a specific species (pigeons). The results of Hemmes (1973) suggest that positive behavioural contrast does not always occur in multiple schedules but depends upon the nature of the operant response under investigation. While her pigeon subjects produced contrast using key pecking as the operant response, there was no evidence of any schedule interaction in the same subjects when they were required to press a treadle instead of pecking a key. Westbrook (1973) also used pigeons pressing a bar, and also reported a failure to demonstrate positive behavioural contrast. However, the occurrence of U-shaped gradients around S2 during later generalization testing implied that the absence of contrast did not reflect an absence of inhibition. The results of Hemmes and Westbrook suggest that the classical conditioning contingencies which strongly affect key pecking in pigeons and are the basis of the additivity account of contrast, do not extend to other response classes.

Reynolds (1961) proposed a kind of matching hypothesis, that the extent of positive contrast depended on the relative amounts of reinforcement in each component. However, later work has contradicted this, e.g. Reynolds and Limpo (1968) using a multiple schedule where only low rates of responding were reinforced, i.e. a mult DRL DRL schedule. Behavioural contrast occurred in the unchanged component but while the response rate decreased in the changed component, the reinforcement rate in that component actually increased.

Bloomfield (1969) and Premack (1969) proposed a "preference" account of contrast, stating that positive behavioural contrast occurred when there was a "change for the worse" in the changed component, and that what constituted such a change could be shown in concurrent schedules, giving a measure of preference.

Terrace (1966) proposed an alternative formulation and saw behavioural contrast as a function of response suppression in the changed component. Freeman (1971) reviewed the evidence dealing with these two major analyses in an article entitled "Behavioral contrast: reinforcement frequency or response suppression?" and stated that the major problem in the interpretation of behavioural contrast studies is the confounding of response rate and reinforcement frequency in the changed component.

Terrace's formulation of behavioural contrast has had a major influence because he incorporated his analysis into a broader context and saw contrast as one of several manifestations of inhibition. His theoretical basis developed out of Amsel's work on frustrative non-reward (e.g. Amsel 1958, 1962), and involved the assumption of an emotional state resulting from response suppression, leading to contrast and to later generalization responding such as peak shift, which were indicative of inhibition. He evolved an errorless discrimination learning method which resulted in the emission of very few responses in the changed component, and postulated that because this procedure, unlike discrimination learning with errors, did not result in the development of either contrast or peak shift, these two phenomena were therefore covariant and their occurrence was indicative of inhibitory processes. In appealing to "inhibition" as an explanation of behavioural contrast, Terrace also drew on an earlier and very influential theory developed by Spence to account for the phenomena of discrimination and generalization.

(ii) Spence's gradient interaction theory

Spence examined the role of differential responding in the development of stimulus control and developed a theory (Spence, 1937) to account for stimulus generalization, i.e. the empirical finding that stimuli other than one associated with reinforcement of a response will also evoke that response. His analysis was a development from Hull's earlier (1929) postulates about the "spread of habit strength". Spence's theory involved five assumptions summarised by Rilling (1977):

"1. Reinforcement of responding to a stimulus (S+) produces an excitatory tendency to respond to S+.
2. Excitation generalizes around S+.
3. Extinction of responding to a stimulus (S-) produces an inhibitory tendency opposite to the tendency associated with S+".
4. Inhibition generalizes around S-.
5. The predicted response to any test stimulus is obtained by subtracting the amount of inhibition to the stimulus from the amount of excitation to the stimulus."

(Rilling, in Honig and Staddon, eds, 1977, p.447)

Operant procedures have been successfully applied to the analysis and isolation of the conditions necessary for the establishment of stimulus control, providing a test of Spence's theory. The standard generalization testing procedure follows that of Guttman and Kalish (1956) who adapted a procedure devised by Skinner (1950, p.201). Following single-stimulus training, Guttman and Kalish's pigeons were presented with eleven test stimuli of different wavelengths, and their response rates in the presence of each were recorded, resulting in gradients with a peak at the wavelength of the original training stimulus. The further the test stimulus was from this training stimulus, the less responding it controlled. This evidence of dimensional stimulus control correlates with Spence's hypothesised gradients of excitation, and parallels Pavlov's (1927) earlier work using classically conditioned responses.

This paradigm has been extended to the analysis of gradients around two training stimuli simultaneously, following a multiple schedule discrimination training procedure.

(iii) <u>Peak shift</u>

Investigations of peak shift follow the general procedure of Hanson (1959) who demonstrated its occurrence in pigeons tested along the wavelength dimension. An extensive review of the area by Purtle (1973) shows it has also been reported along a variety of dimensions in several species, ranging from the octopus (Wells and Young, 1970) to humans (Nicholson and Gray, 1971).

Spence's (1937) postulates predict peak shift. According to his formulation, the obtained post-discrimination training generalization is a consequence of the interaction of excitatory (inverted-U) gradients around S1 and inhibitory (U-shaped) gradients around S2. The summation of these tendencies around both stimuli predicts both positive and negative peak shift.

The occurrence of these hypothetical gradients around each stimulus needs to be ascertained independently as a further test of Spence's theory.

Guttman's (1959) procedure provides a measure of independent excitatory gradients around S1. A comparable procedure has been developed as a direct measure of gradients around S2.

(iv) Inhibitory dimensional stimulus control

The inhibitory equivalent of Guttman's procedure was reported by Jenkins and Harrison (1962) and Honig, Boneau, Burstein and Pennypacker (1963). Jenkins (1965) suggested the label "inhibitory" be assigned to the obtained U-shaped gradients around S2.

These gradients are obtained following the second type of discrimination training, viz. interdimensional training, in which the test dimensions of S1 and S2 are psychologically independent, thereby avoiding any of the interaction effects that occur during generalization testing after intradimensional training. Hearst (1969b) examined post-discrimination training, and the independent gradients obtained around S1 and S2 after interdimensional training. From any two of these three empirically derived gradients, the third could be predicted using Spence's gradient interaction theory. He found a "rather high" correspondence between these derived and actual gradients, thus providing support for Spence's theory. Similarly, Marsh (1972) obtained gradients as predicted, using stimuli along the wavelength dimension.

(v) Behavioural contrast, peak shift, and inhibitory stimulus control

Hearst (1969) is not alone in examining the relationship between peak shift and U-shaped gradients around S2. Thomas and Williams (1963) and Terrace (1966a) also suggest that peak shift is the result of the formation of an underlying inhibitory gradient around S2, and Weisman (1969) and others have shown this to be so even when S2 is correlated with schedules other than extinction. Terrace (1966b) indicated the reverse of this using the errorless learning procedure and comparing this with the usual procedure of learning with errors. Not only had the errorless procedure failed to produce peak shift (Terrace 1966a) but it also resulted in flat stimulus generalization gradients after interdimensional training (Terrace, 1966b).

Similarly, Terrace (1968) observed that behavioural contrast was a necessary antecedent of peak shift and it has also been described as a necessary antecedent of inhibitory stimulus control after interdimensional training (Farthing and Hearst, 1968; Terrace, 1971; Weisman, 1969; Yarczower, 1970).

(vi) Hearst, Besley and Farthing (1970)

The concept of inhibition has been frequently used to account for behavioural contrast, peak shift and U-shaped gradients around S2, despite the earlier lack of popularity of such a concept within the context of the experimental analysis of behaviour as a result of Skinner's (1938) criticism of its experimental basis and logical status. The important question is not whether inhibition is a physiological reality comparable with Pavlov's (1927) account implying waves of inhibition spreading across the cortex, but rather whether an inhibitory construct is essential for the prediction of behaviour. Skinner maintained it was nothing more than a reduction in excitation.

There are two main approaches: Terrace (1966a) defined inhibitory functions of stimuli in terms of their dimensional control over responding, whereas Jenkins (1965) said it was the development of a response to S2 incompatible with the reinforced response. Hearst, Besley and Farthing's (1970) monograph provided a much-needed resolution of this issue by delineating separate and distinct inhibitory processes that are empirically obtainable.

They defined an excitatory stimulus as one controlling a higher rate of responding than that which occurs in its absence, and an inhibitory stimulus as one that decreases the response rate below what would occur in its absence. They distinguished these properties from those of excitatory and inhibitory dimensional control exerted by stimuli, where the former refers to the development of decremental (inverted-U) gradients around a stimulus, and the latter, to the development of incremental gradients.

However, an incremental gradient on its own would not define that stimulus as inhibitory, but this must be demonstrated by an independent test (see Hearst, Besley and Farthing, 1970, p.p. 376-377). Their classification has been widely adopted in studies of stimulus control, as have the several different types of generalization test they described, measuring different aspects of inhibitory stimulus control (see Rilling, 1977). A further discussion of these is given in Experiment 3, Chapter V.

2. THE CURRENT SERIES OF EXPERIMENTS

While most studies on discrimination training have employed a *mult* VI EXT paradigm, S2 has also been correlated with other schedules in the production of positive behavioural contrast, peak shift, or inhibitory dimensional stimulus control. The research reported here systematically compared stimulus control following two training procedures to see whether these two procedures produced equivalent effects and also to see whether in fact the phenomena mentioned above did covary as predicted by Terrace (1966a).

The first of the two training procedures used was *mult* VI EXT, to provide comparability with the bulk of the stimulus control literature. The other training procedure involved the use of signalled reinforcement in the S2 component, a procedure which typically reduces response rates without altering the reinforcement density or interreinforcement interval.

(i) Signalled reinforcement

A signal of reinforcer availability (SIG) has been used in a variety of schedules. Brownstein and Newsom (1970) found it effectively reduced S2 responding in a fixed-interval (FI) schedule. They obtained positive behavioural contrast during *mult* FI-2 FI-2(SIG). Contrast has also been reported following multiple schedules using variable interval reinforcement, by Baldock (1970), Baldock and Blampied (1970), Brownstein and Hughes (1970), Lander (1971), Marcucella (1976) and Thompson and Corr (1974). Reynolds and Limpo (1968) obtained positive behavioural contrast in a *mult* DRL DRL schedule where the unchanged component was associated with the reinforcement of interresponse times greater than 35sec (i.e. DRL 35-sec) and the other component included a clock indicating interresponse times. The use of the clock is a variation on signalled reinforcement, and contrast occurred even though there was a higher reinforcement rate in the changed component.

More complex schedules have also been used with signalled reinforcement. Blampied (1972) obtained positive behavioural contrast in the terminal link of a concurrent chains schedule. Others have reported the effect of this procedure on phenomena other than behavioural contrast. Bower, McLean and Meacham (1966) reported that choice was unaffected by signalling reinforcement availability in a concurrent chains schedule. Lewis, Lewin, Muehleisen and Stoyak (1974) reported a preference for signalled reinforcement in terms of time spent in the presence of this condition although this preference was not matched by a higher response rate. They used a change-over key which may have accounted for the difference between their results and those of Bower et al (1966). Pliskoff and Green (1972) had also reported a preference for the key colour in the presence of which the reinforcer signal was operative, and Wilkie (1973) reported a failure to observe consistent preference for the non-signalled component of a concurrent VI VI schedule, a finding which is also consistent with those of Lewis et al (1974) and Pliskoff and Green (1972).

Baldock and Blampied (1970) used inter-dimensional training where S2 was three vertical black lines on a white background, and the signal, a 1000Hz tone. Generalization testing along the line orientation dimension did not reveal inhibitory gradients, whereas generalization testing along this dimension in the presence of two tones produced excitatory gradients.

These results suggest that SIG may have similar effects to EXT as a response-suppression procedure during discrimination training. The experiments to be reported in this series investigate whether it also results in inhibitory stimulus control as measured by intra- and interdimensional methods.

(ii) The line orientation dimension

The line orientation dimension was used throughout these experiments, with the exception of Experiment 2. The use of this dimension in the investigation of stimulus control thereby provides comparability with the work of many others who have used it in the context of either intra- or interdimensional discrimination. These researchers include Davis (1971), Farthing (1972), Farthing and Hearst (1968), Hanson (1959), Hearst (1968), Hearst, Koresko and Poppen (1964), Hearst, Taus and Koresko (1971), Hirota and Clarkson (1973), Honig, Boneau, Burstein and Pennypacker (1963), Malone and Staddon (1973), Nicholson and Gray (1971), Taus and Hearst (1972), Thomas and Lyons (1968), Weisman (1969), White (1972), Wilkie (1972), Winton and Beale (1971), Yarczower (1970), Zentall (1972) and Zentall, Collins and Hearst (1971).

CHAPTER II

GENERAL METHOD

1. SUBJECTS

The subjects were experimentally naive homing pigeons bred and reared in the Psychology Department of the University of Canterbury. For the duration of the experiment in which they were used, they were housed indoors in individual cages and maintained at 80% (±10g) of their free-feeding body weights. Water and grit were freely available in the home cages, and prescribed body weights were maintained by supplementary feeding, comprising a mixture of pigeon peas and wheat. Forty-six subjects were used, six in Experiment 1 and eight each in Experiments 2 to 6.

2. APPARATUS

The experimental apparatus was a standard pigeon chamber (Grason-Stadler pigeon station model E6446CA-1 within a Grason-Stadler animal chest model E3125AA-3) containing three plexiglas keys. The only operandum and site of the discriminative stimuli was the centre key, diameter 2 cm, situated 22 cm above the floor. The force required to operate the microswitch mounted behind the key was approximately 0.18N. The reinforcer was 4-second access to wheat delivered from an illuminated hopper through an aperture 4.5 cm high and 5 cm wide located 12 cm below the centre key. During the signalled-reinforcment condition, a 1.2-W lamp in a translucent plastic housing, 1 cm in diameter, 14 cm to the right of the centre key and 24 cm above the floor, was illuminated when a reinforcer was scheduled and during its delivery. This signal had an illumination of 292 lx, measured by a Toshiba Photocell Illuminometer model SPI-5. These were the only sources of illumination in the chamber. During Experiments 1 and 2, the key was transilluminated using a Grason-Stadler multiple stimulus projector. For Experiments 3 to 6, stimuli were projected on to an opaque screen 1 cm behind the key by a Kodak Carousel projector (S-AV 2000, Type F) (for Experiment 3) or an Agfacolor 250W AV projector (Experiments 4 to 6) mounted outside the chamber. The light source was a 150W tungsten halogen lamp. The projector was set on low illumination and a 1.0 n.d. wratton filter no. 96 and an iris diaphragm were set in front of it to reduce the light intensity impinging on the key to a standard 30 lux without slides. General masking noise was provided by the exhaust fan used for ventilation. Electromechanical relay control and recording equipment was located in an adjacent room.

3. PROCEDURE

This is an outline of the basic procedure followed in all the experiments. More detailed outlines of procedural variations in each experiment will then be given.

(i) Preliminary training

When subjects had reached 80% free feeding weight, they were adapted to the experimental chamber and magazine trained. All keys were dark and the houselight was off. In session 2 they were trained to peck the key using a procedure similar to that of Brown and Jenkins (1968). The chamber was dark except during stimulus-food pairing trials, each of which comprised illumination of the key for 8 seconds. At the offset of the key light the hopper was raised for 4 seconds. Pecks to the lit key turned the key light off and the hopper was immediately presented. Key pecks during the intertrial interval had no scheduled effect, whereas in the Brown and Jenkins study, such pecks delayed the next trial for 60 seconds. Brown and Jenkins scheduled trials on an average of one every 60 seconds, but in this study they were scheduled on an average on one every 30 seconds(VT-30sec schedule), a schedule also used by Tomie, Davitt and Engberg (1976). All schedules used were developed according to the progressions given by Fleshler and Hoffman (1962). After a burst of responding occurred, the autoshaping procedure was halted, the key light was kept on constantly and responding was reinforced on a schedule progressively increasing the average interreinforcement interval from continuous reinforcement to an average of 30 sec(VI-30sec). The session ended when 80 reinforcers had been delivered. In session 3 the schedule was increased from VI-30sec to VI-60sec until 50 reinforcers had been delivered.

(ii) Baseline training

A two-ply multiple schedule with identical variable-interval 60-sec schedules associated with each component (MULT VI-60sec VI60sec) constituted the nondifferential or baseline phase for all experiments except Experiments 3 and 6. The baseline training procedures for these experiments will be outlined later in the detailed Method section for each experiment. Each session lasted about35 minutes and comprised 15 1-minute presentations of each of the stimuli, S1 and S2, associated with the two components. Between stimuli presentations there was a 6-sec blackout during which the response key was dark and inoperative and the tapes controlling the reinforcement schedule were stopped. The order of presentation of S1 and S2 during each sessions was determined using Gellermann series (Gellermann, 1933), which were developed for use in discrete-trial visual discrimination experiments, giving

> "orders of alternating stimuli in which the most probable chance score would be 50% correct" (p. 206)

The use of these series is appropriate also to these free-operant discrimination experiments for minimising cue effects resulting from the order of presentation of the discriminative stimuli. Baseline training was discontinued after 20 daily sessions, provided responding during the last six sessions met the following criterion of stability:-

$\bar{x}$(sessions 1 to 3) - $\bar{x}$(sessions 4 to 6) < 10% $\bar{x}$(sessions 1 to 6)

This criterion was adapted from Schoenfeld, Cumming and Hearst (1956), who used 5% of the grand mean as their cutoff point.

(iii) <u>Baseline generalization test</u>

A baseline generalization test was given to all subjects to provide a standard against which to compare performance on the post-discrimination training generalization test, and thus assess the contribution of the pre-experimental factors to the final obtained gradient. The procedure adopted for the generalization testing followed as closely as was practicable, that in effect during baseline training, in terms of such parameters as deprivation level, and length of session, stimulus presentation, and blackout. The baseline generalization test was given on the day following the final session of baseline training. The test comprised an initial "warm-up" period constituting four 1-minute presentations of each of the training stimuli, S1 and S2, reinforced on the MULT VI-60sec VI 60sec schedule. Immediately afterwards the test stimuli were presented. The number and nature of the stimuli varied from experiment to experiment but the same basic procedure applied. The test stimuli, including both training stimuli, were presented in randomised order for 1-min each, separated by a 6-sec blackout. During testing no responses were reinforced. A further warm-up period of two 1-min presentations of each of the training stimuli in MULT VI-60sec VI-60sec followed, and finally there was a second testing series, again in extinction.

(iv) Discrimination training

On the day following the baseline generalization test, the discrimination training phase began. The procedure was identical to that of the baseline training phase except for the reinforcement schedule in effect. One stimulus, S1, remained associated with the VI-60sec schedule, but the other stimulus, S2, was now associated with either of two discrimination training procedures. For some subjects, S2 was now associated with extinction, giving a discrimination training procedure of MULT VI-60sec EXT. For other subjects, the discrimination training procedure involved signalled reinforcement. In this procedure the only difference between baseline and discrimination training was that in the latter, the availability of reinforcement in the S2 component was signalled by the onset of the houselight, which remained on until and during the delivery of the reinforcer. Key pecks were reinforced only in the presence of this added signal: for the rest of the time that the S2 component was in operation, no responses were reinforced. The signal light never came on during S1 presentations. This schedule is referred to as MULT VI-60sec VI60sec(SIG).

Discrimination training continued until response rates had stabilised.

(v) Post-discrimination training generalization test in Extinction

The procedure for the post-discrimination training generalization test, which was conducted on the day following the last session of discrimination training, was identical to that of the baseline generalization test, except for the reinforcement schedule in effect during the warm-up phases. This now consisted of presentation of S1 and S2 associated with the appropriate schedule in effect during discrimination training, in either MULT VI-60sec EXT or MULT VI-60sec VI-60sec(SIG).

4. DISCUSSION OF GENERAL METHOD

It is appropriate to discuss here the rationale behind the procedures adopted in the experiments to be described.

a. A two-ply MULT VI VI schedule was used because it can be regarded as a standard training procedure for investigations of discrimination. Ferster and Skinner (1957) pointed out that a VI schedule in contrast to fixed-interval (FI) and fixed-ratio (FR) schedules, typically produces

> "a constant [response] rate by not permitting any of the bird's behavior to acquire discriminative properties". (p. 326)

Responding within each component of a MULT VI VI schedule develops into a steady and sustained rate, although with some small local changes produced by a particular set of intervals this stable performance serves as a baseline against which the effects of schedule and other changes can be assessed. Hanson's (1959) use of pigeons in a 2-component multiple schedule has provided a procedural paradigm for the investigation of stimulus control.

b. Baseline generalization test: Most experiments concerning dimensional stimulus control follow Hanson's (1959) procedure of discrimination training followed by a generalization test, but without a previous baseline generalization test conducted prior to discrimination training. However, the results obtained by Peterson (1962) and Tracy (1970), among others, provide a salutary warning that previously acquired discriminations may transfer to the testing situation and result in differential responding which is not related to the specific discrimination training procedure used. It has become standard procedure when investigating the effects of discrimination training on dimensional stimulus control to do generalization testing only after the training, without a baseline generalization test for comparison (e.g. Rilling, Caplan, Howard and Brown, 1975; Rosen and Terrace, 1975; Terrace, 1975; Thomas and Burr, 1969; Winton, 1975).

However in the experiments to be described here, there was both a baseline nondifferential training period to ensure equal responding to both training stimuli and a baseline generalization test thereafter, which provided a measure of the extent of the contribution of pre-experimental or non-specific factors to the shape of the generalization gradients. Any differences in the shape of the baseline and post-discrimination training generalization tests could then confidently be said to result from the interpolated discrimination training.

c. Testing procedure: Thomas and Burr (1969) showed that the length of the delay period between training and generalization testing affected the shape of the generalization gradients. They gave pigeons successive discrimination training and then tested along the wavelength dimension, and found that

> "a 24-hr delay between training and testing for generalization produced both a greater peak shift and a flatter gradient than that obtained on an immediate test" (p. 108),

but that a 3-min warm-up period immediately before testing eliminated such differences, i.e. the subsequent generalization gradients were the same shape as those obtained when testing was conducted immediately following training. The warm-up period preceding each testing session is usually about the three minute duration discussed by Thomas and Burr, but there are exceptions in the literature. Rilling, Caplan, Howard and Brown (1975) for example preceded each session of testing with 28 trials of discrimination training. The great advantage in conducting the generalization test on the day following the final training session was that the deprivation levels were the same during training and testing. If testing had been carried out immediately following the final training session, the deprivation level of the subjects would have been lower than during training, resulting in a lowering of absolute response rates. Thomas and Burr reported that absolute response rates during the generalization test were lower in the subjects tested immediately after training than in those tested one day later. However, they reported that the absolute rate difference made no substantial difference to the shape of the obtained gradients.

Many studies of dimensional stimulus control follow the pattern set by Guttman and Kalish (1956) in having a shorter duration of stimulus presentation during generalization testing than during training. In their study pigeons were given single-stimulus training and then tested along the wavelength dimension. During training the stimuli were presented for 60 sec, separated by blackouts of 10-sec duration; but during generalization testing the stimuli were presented for only 30 sec, separated by 10-sec blackouts. This pattern was also adopted by Thomas and Burr (1969). Many researchers adopt the pattern reported by Dysart, Marx, McLean and Nelson (1974), viz. 3-min stimulus presentations during training and 30-sec presentations during generalization testing. The literature on transient contrasts effects (e.g. Nevin and Shettleworth, 1966, Staddon, (1969) emphasizes the occurrence of local response rate changes which would have a greater bearing on overall response rates in short stimulus presentations than in longer ones. Therefore, in these experiments the stimulus presentations were of equal length during training and testing to eliminate the differential effects of such phenomena. Farthing and Hearst (1968), Jenkins and Harrison (1962), Rilling, Caplan, Howard and Brown (1975), Rosen and Terrace (1975) and Terrace (1975) are among those who have also adopted this approach.

d. The generalization test data are presented as relative response rates, which give the response rate to each stimulus during testing as a fraction of the total number of responses to all test stimuli during that testing session. This procedure equates for differences in the number of responses made during testing and enables direct comparison of the slopes of the gradients, and location of maxima and minima, independent of the height of individual gradients. Various transformations into relative gradients have been used for some time, as was noted by Lyons (1969):

> "The use of percent gradients has become common practice in the scientific literature (cf. Hearst, Koresko and Poppen, 1964; Switalski et al, 1966; Thomas and King, 1959)".

The choice of the measure of relative generalization appears to have been somewhat arbitrary, but there are two basic types. The first, as adopted here, is to convert each response value on the gradient to a percentage or fraction of the total responses to all test stimuli during generalization testing. This procedure was also used by Hearst, Taus and Koresko (1971), Farthing (1972), and Farthing and Hearst (1968). The other popular method for converting absolute into relative response rates to enable the comparison of two generalization gradients, expresses responding to a test stimulus as a fraction of the responding to the training stimulus. Farthing and Hearst (1972), for example, assigned S^+ the value of 1, and all other stimuli fractions of this. Hearst (1969, p. 238) used the highest response rate as the standard (i.e. not necessarily responses at S^+) and expressed all other response frequencies as decimal fractions of this value. The use of relative measures can be criticised particularly in situations where comparisons are to be made between successive gradients obtained from the one subject rather than between different subjects, as the implied model of constant probabilities does not hold: Hearst (1969) showed that the ratio sometimes fails to remain constant, with sharpening relative gradients during extinction. If these gradients had been measured in absolute terms, the relative differences would have remained constant during extinction, and this would have avoided the absurd situation of a demonstration of improved discrimination ability as a result of extinction. However, in the present experiments the need to transform generalization test data into relative response rates is well justified as the only way to compare two or more different response rates which all change as a result of experimental manipulation. This procedure tells us whether or not the difference between the two response rates has changed.

e. Stability of responding during training:

There are several possible measures of stability that could have been used, but all have their disadvantages. A frequently used measure of differential responding in each component is the Discrimination Index (DI):

$$D.I. = \frac{R_1}{R_1 + R_2}$$

Where R_1 = response rate in S1

R_2 = response rate in S2

Equal responding in both components gives a DI of 0.5. But the disadvantage in the context of these experiments, where comparisons are made between response rates during two conditions of training, is that a stable DI could be obtained while response rates in both components are decreasing. Also, increases in DI during discrimination training may result from an increased response rate in S1, decreased response rate in S2, or some combination of these.

The discrimination ratio (DR): $\frac{R_1}{R_2}$ has the advantage over the DI as a measure of stability of responding in that it allows for increases in response rate to be recorded. If the response rate is the same in each component, DR = 1. However, this still gives no indication of change if the response rate in both components is increasing. A further problem is that when the response rate in S2 is zero, the DR approaches infinity, for any size of R.

Therefore, the stability criterion adopted in this series of experiments (after Schoefeld, Cumming and Hearst, 1956), was chosen because it provides a measure of variations in response rates. It is therefore especially relevant to experiments considering the occurrence of positive behavioural constrast, a defining characteristic of which is an increase in response rate in an unchanged component.

f. Measures of behavioural contrast:

There are several ways of assessing behavioural contrast reported in the literature, and the variety of measures used limits the comparability of studies adding to the complexity of this area of research. Some workers (e.g. Couch, 1975; Hemmes, 1973; Keller, 1974; Richards, 1972; Vieth, 1972; Westbrook, 1973) report only untransformed data, presenting graphs or tables of response rates and evaluating the contrast effect by inspection of these. Bilbrey and Winokur (1974) and Sadowsky (1973) presented percentage change in response rate between baseline and discriminative training. Bilbrey and Winokur computed the percentage difference between the last four baseline sessions and the first four extinction (discrimination training) sessions, and Sadowsky compared groups of subjects to determine the peak rate of responding by taking the highest daily rate in the first ten days of discrimination training as a percentage increase over the mean of the last ten days of pretraining. Kodera and Rilling (1976) defined behavioural contrast as a difference of one standard deviation between the response rate of the last five days of one phase and the first five days of the other.

Statistical analyses, usually analysis of variance have been used by some researchers including Gonzalez and Champlin (1974), Pert and Gonzalez (1974), and Richards (1975), to evaluate contrast effects. Kodera and Rilling (1976), however, warn against the use of parametric statistics on comparisons of group means if they violate the homogeneity of variance rule, and they therefore used the Mann Whitney U test to evaluate their data, as did Boakes, Halliday and Mole (1976), and Halliday and Boakes (1974). The disadvantage of the use of such statistical measures is again that the data being analysed are not the same for different researchers: e.g. Boakes et al (1976) compared changes in median response rate from baseline to experimental conditions but Kodera and Rilling (1976) compared group means. Gonzalez and Champlin (1974) and Richards (1975) both performed treatment by subject analyses, but Gonzalez and Champlin used five consecutive blocks of four days, and Richards, seven five-day blocks.

Statistical analyses such as these are not reported on the data of the experiments in this series. Rather, discrimination training data are presented so that an evaluation can be made not of grouped data, but of individual subjects in each group. These data are presented as normalised response rates. This transformation has been used previously: Brownstein and Hughes (1970) and Brownstein and Newsom (1970) determined the mean response rate for the last five days of pretraining and assigned this as 1.00, comparing response rates during discrimination training to this standard. Wilkie (1973) also normalised data by assigning a value of 1.00 to the mean of the last seven baseline sessions.

In this series of experiments, the normalised response rate is calculated by dividing the response rate in a component by the mean response rate in that component during the final six days of baseline training, for each subject. These were the same six days from which discrimination indices were calculated. The mean of the six sessions was thus denoted as 1.00.

The extent to which the S1 response rate rose above 1.00 during discrimination training gives a measure of the amount of positive behavioural contrast exhibited by that subject, and the extent to which the S2 response rate decreased below 1.00 gives a measure of response suppression in the changed component. The purpose of presenting the data this way rather than as absolute response rates is to minimise inter-subject differences in response rates to get a direct comparison across subjects of the occurrence and extent of both positive behavioural contrast and response suppression. The drawback of the use of normalised data is that high responders may then appear to demonstrate little change in rate but may in fact in absolute terms have increased or decreased more than other subjects. The absolute response rates from which the normalised data were derived are presented in the Appendices so that such inter-subject differences can be assessed.

CHAPTER III

EXPERIMENT 1

1. AIM

To compare stimulus control following discrimination training using either extinction or signalled reinforcement to suppress responding in S2.

2. METHOD

This was outlined in General Method, with the following specific characteristics:

(i) Subjects:

J1 J2 J3 J4 J5 and J6

(ii) Procedure:

a. Baseline training

An intradimensional training procedure was used. The two components of the MULT VI-60sec VI-60sec schedule were denoted by two different orientations (30° and 60°) of a black line on a white background. (All line orientations are labelled such that 0° denotes the horizontal and 90° the vertical.)

b. Pre-discrimination training generalization test

The seven test stimuli were the following orientations of a black line on a white background: 0°, 15°, 30°, 45°, 60°, 75°, and 90°.

c. Discrimination training

Table 3.1 shows the stimuli and associated reinforcement schedules for each subject in Experiment 1. Stimuli were designated as S1 and S2

Table 3.1

Experiment 1:

Stimuli and reinforcement schedules in effect during discrimination training.

Subject	S1 (VI-60sec)	S2	S2 schedule
J1	30^{o}	60^{o}	VI-60sec(SIG)
J2	30^{o}	60^{o}	VI-60sec(SIG)
J3	60^{o}	30^{o}	VI-60sec(SIG)
J4	60^{o}	30^{o}	VI-60sec(SIG)
J5	60^{o}	30^{o}	EXT
J6	30^{o}	60^{o}	EXT

according to the following criteria:

(i) Equal numbers of subjects were assigned each of the two training stimuli as S2.

(ii) Within the constraints imposed by (i), a stimulus was designated as S2 for a subject if the subject had shown a slightly higher response rate to that stimulus during nondifferential baseline training.

d. Post-discrimination training generalization test

The same procedure was followed as for the prediscrimination training generalization test, except that during the warm-up periods the reinforcement schedules in effect were the same as those in effect during discrimination training.

3. RESULTS

(i) Baseline and discrimination training

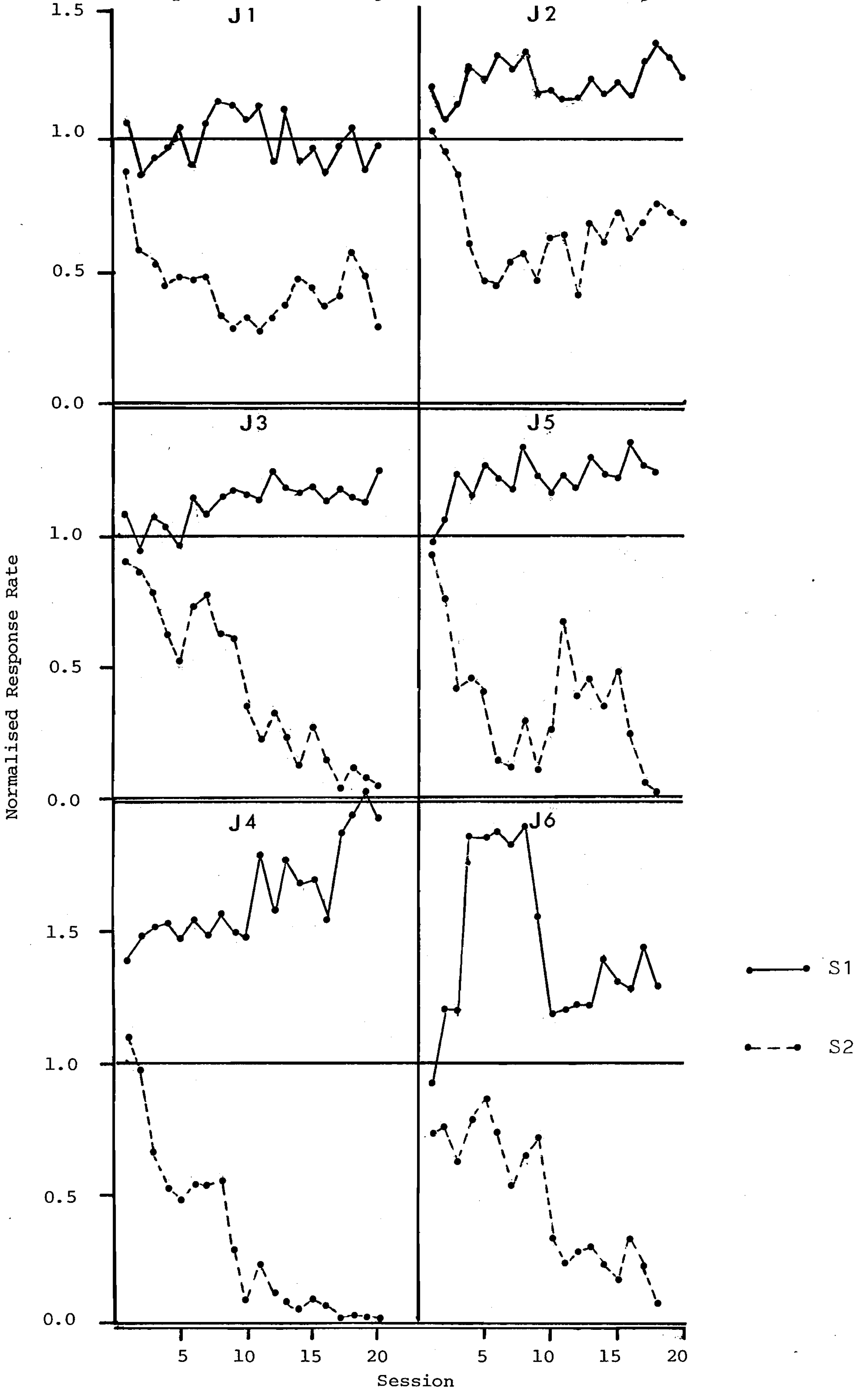
Figure 3.1 shows for each subject the normalised response rates for both the changed and unchanged components of the multiple schedule during discrimination training. In the SIG group (i.e. those subjects for which discrimination training was the MULT VI-60sec(SIG) condition), three of the four subjects (J2, J3 and J4) gave clear evidence of positive behavioural contrast, but the S1 response rate of the fourth subject (J1) did not change from its baseline. However, all four subjects showed response suppression in S2, although to different degrees.

Figure 3.1

Experiment 1: Normalised response rates of each subject in each component on successive days of discrimination training. The normalised response rate was calculated by assigning a value of 1.00 to the mean of the final six sessions of baseline training. Discrimination training for J1, J2, J3 and J4 was MULT VI-60sec VI-60sec (SIG) and for J5 and J6 it was MULT VI-60sec EXT.

Figure 3.1

Normalised response rates for both components of the multiple schedule during discrimination training



Both subjects in the EXT group (i.e. trained on MULT VI-60sec EXT) exhibited positive behavioural contrast in S1 and response suppression in S2. Table 3.2 gives the discrimination indices for all subjects for the last six sessions of the baseline and discrimination training phases, showing clear differential responding by all subjects.

(ii) Generalization testing

Figure 3.2 presents the relative response rates of individual subjects during both the pre- and post-discrimination training generalization tests. In each case there is a marked difference between pre- and post-discrimination training gradients, indicating the acquisition of dimensional stimulus control along the line orientation dimension as a result of intradimensional discrimination training on that dimension. The pre-discrimination training generalization tests all produced relative response around 0.14, indicating near equal response rates to all stimuli. However, in the post-discrimination tests, all four subjects in the SIG group responded maximally to S1, and all except J3 responded minimally to S2. But despite the fact that J3 had lower response rates to stimuli other than S2, the shape of the generalization gradient clearly indicates the same trend as the gradients of the other SIG subjects, viz. a peak at S1 and a trough at S2.

In contrast, both EXT subjects showed peak and

Table 3.2

Experiment 1:

Discrimination indices for the final six sessions of baseline and discrimination training.

$$DI = \frac{S1}{S1 + S2}$$

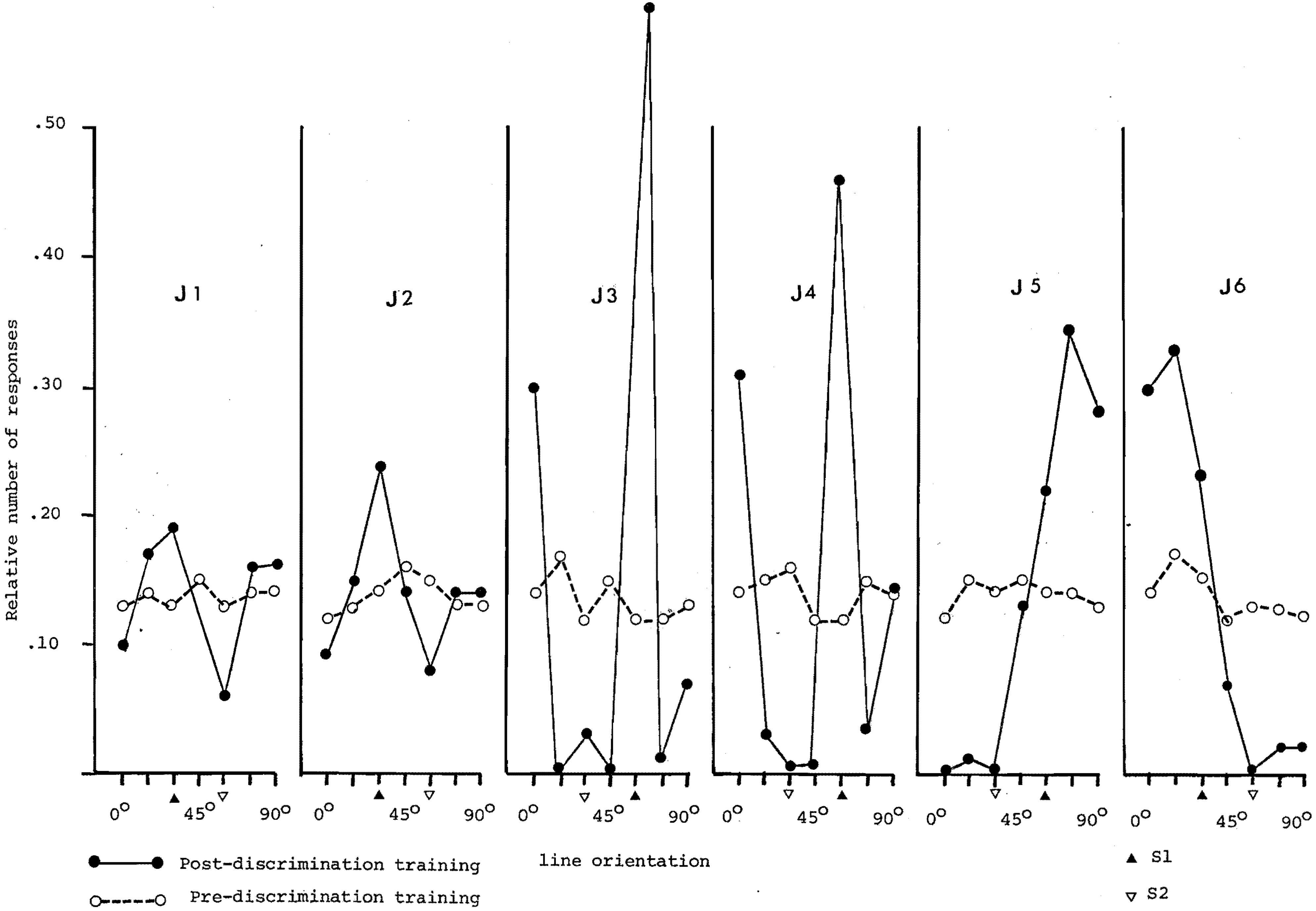
where S1 and S2 represent total responses in each component for the final six sessions of each phase.

Training procedure	Subject	Baseline	Discrimination
SIG	J1	.49	.68
SIG	J2	.49	.64
SIG	J3	.50	.91
SIG	J4	.47	.98
EXT	J5	.49	.82
EXT	J6	.48	.84

Figure 3.2

Experiment 1: Pre- and post-discrimination training generalization gradients along the line orientation dimension expressed as relative response rates for all subjects.

Figure 3.2



.50
.40
.30
.20
.10
Relative number of responses
J1
J2
J3
J4
J5
J6
0°
45°
90°
line orientation
Post-discrimination training
Pre-discrimination training
S1
S2

area shift.

4. DISCUSSION

Terrace's (1966) theory of stimulus control has maintained that behavioural contrast, peak shift following intradimensional training, and inhibitory dimensional stimulus control following interdimensional training, are phenomena which are determined by the same variables and they should therefore covary. He states that:

> "The reduction of rate of responding in the presence of one discriminative stimulus relative to the rate of responding as maintained in the presence of another discriminative stimulus is a sufficient condition to make the stimulus correlated with the reduction of response rate an aversive one" (in Honig, 1966, p. 332).

He supports this proposal that stimuli become aversive after being associated with response reduction, with this further evidence: first, the impermanence of positive contrast; second, that in all experiments in which peak shift was obtained, contrast had also occurred; and third, the occurrence of emotional behaviour of the pigeons when presented with a negative stimulus during discrimination training.

The third of these proposals (occurrence of emotional behaviour) was not under direct or systematic study in this experiment and so cannot be dealt with.

The first, i.e. the impermanence of positive behavioural contrast, is not directly supported. All subjects showing contrast maintained a higher response rate in S1 throughout discrimination training than they had previously, during the baseline phase. There is however a clear reduction in the amount of contrast shown by J6 after the 10th session, but even in this subject, the response rate in that component did not return to baseline levels. Terrace's claim of the inevitability of a decline in behavioural contrast with extended training has also been disputed by Rilling, Askew, Ahlskog and Kramer (1969) and Hearst (1971).

The second of Terrace's proposals, i.e. the the covariation of peak shift and positive behavioural contrast, was demonstrated by the EXT group, a result that has been demonstrated many times previously (Hanson, 1959; Terrace, 1966). But the SIG group results, showing the occurrence of contrast without subsequent peak shift suggests that:

a. not all methods of response suppression result in peak shift during generalization testing.

b. These two by-products of discrimination learning do not always covary.

In these ways SIG has differed from other response-suppression procedures, e.g. lower rate of reinforcement (Guttman, 1959; Terrace, 1968; Weisman, 1969); differential reinforcement of a lower response rate (DRL) (Terrace, 1968, Bloomfield, 1967; Weisman, 1969); delayed reinforcement (Keller, 1970; Mariner and Thomas, 1969; Richards, 1972; Wilkie, 1971; Wilkie, 1972);

and shocks (i.e. punishment for responding in S2) (Grusec, 1968; Coates, 1972; Brethower and Reynolds, 1962; Terrace, 1968).

However, conclusions drawn from this experiment must remain tentative until these phenomena are subjected to further investigation. Therefore the effects of these two response suppression methods (EXT and SIG) must be evaluated along a different stimulus dimension, to assess the generality of these findings.

CHAPTER IV

EXPERIMENT 2

1. AIM

The results of experiment 1 indicate that while the two response-suppression procedures (SIG and EXT) both result in the occurrence of positive behavioural contrast, only the EXT procedure produces peak shift in later generalization testing. The purpose of this second experiment is to investigate how general these results are: would the same results be obtained if another stimulus dimension were used in place of the line-orientation dimension? Therefore in this second experiment the same phenomena were investigated along the stimulus dimension of flicker rate.

2. METHOD

This was as outlined in the General Method and Experiment 1, but with the following specific characteristics:-

(i) Subjects:

8 subjects: A1 to A8.

(ii) Procedure:

a. Baseline training

Again, an intradimensional training procedure was used. The two components of the MULT VI-60sec VI-60sec schedule were denoted by two different flicker rates. The key was illuminated with a red light of 0.1 sec duration alternated with a green light of different durations. For the training stimuli, these durations of green-light flash were 0.6 sec and 2.2 sec.

b. Pre-discrimination training generalization test

Table 4.1 gives the stimulus durations of the test stimuli used.

c. Discrimination training

Table 4.2 shows the stimuli and associated reinforcement schedules for each subject in Experiment 2.

d. Post-discrimination training generalization test

The procedure was the same as for that of the baseline generalization test, except that the reinforcement schedules in effect during the warm-up periods were the same as those in effect during discrimination training.

3. RESULTS

(i) Baseline and discrimination training

The normalised response rates for both the changed and unchanged components of the multiple schedule during discrimination training are shown in Figure 4.1. None of the subjects showed a consistently higher rate of responding to either stimulus during baseline training.

As can be seen from Figure 4.1, seven of the eight subjects showed positive behavioural contrast. The other subject, A4, never developed a substantial differential response rate, showing neither response suppression with signalled reinforcement, nor an

Table 4.1

Experiment 2:

The rates of flicker used as stimuli.

Stimulus number:	1	2	3	4	5	6	7
Stimulus duration[a]:	0.2	0.6	1.0	1.4	1.8	2.2	2.6

[a] The duration in seconds of successive onsets of the green light interspersed with a standard 0.1 sec red light.

Table 4.2

Experiment 2:

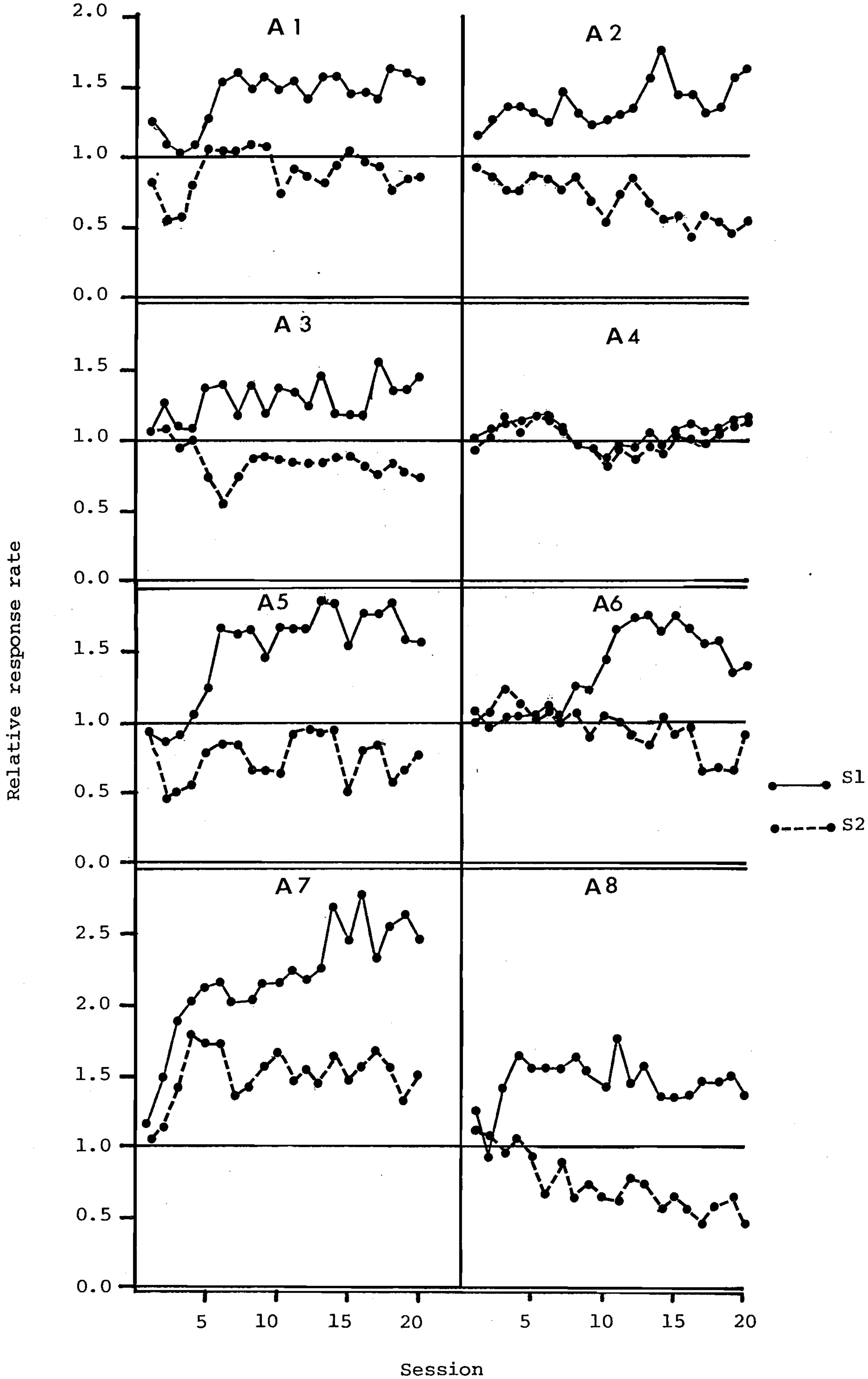
Stimuli and reinforcement schedules in effect during discrimination training.

Subject	S1 (VI-60sec)[a]	S2	S2 schedule
A1	2.2	0.6	VI-60sec(SIG)
A2	2.2	0.6	VI-60sec(SIG)
A3	0.6	2.2	VI-60sec(SIG)
A4	0.6	2.2	VI-60sec(SIG)
A5	0.6	2.2	EXT
A6	0.6	2.2	EXT
A7	2.2	0.6	EXT
A8	2.2	0.6	EXT

Figure 4.1

Experiment 2: Normalised response rates of each subject in each component on successive days of discrimination training. The mean response rate of the final six sessions of baseline training for each component is given a value of 1.00.

Figure 4.1


A 1
A 2
A 3
A 4
A5
A6
A7
A8
2.0
1.5
1.0
0.5
0.0
2.5
Relative response rate
S1
S2
5
10
15
20
Session

an increased response rate in the unchanged component. However, while A4 was the only subject which failed to discriminate between the stimuli, it was not the only subject which did not show substantial response suppression. Although A1 showed a marked degree of positive behavioural contrast, this subject showed response suppression in S2 (SIG) only initially, i.e. in sessions two, three and four, and by the fifth session of discrimination training had returned to its former (i.e. baseline) level of responding. A similar pattern is also shown by A6, with little response suppression in S2 (EXT), yet with clear evidence of positive behavioural contrast as demonstrated by a substantial increase in response rate in the unchanged (S1) component. A7 showed an increase in response rates in both components during discrimination training (positive induction). The data shown in Figure 4.1 show no predictable relationship between the occurrence or magnitude of behavioural contrast in one component, and occurrence or magnitude of response suppression in the other.

Table 4.3 gives the discrimination indices for all subjects. Each DI is the mean of the final six sessions of the baseline and discrimination training phases.

(ii) Generalization testing

The results of the pre- and post-discrimination training generalization tests are shown as relative response rates in Figure 4.2. The pre-discrimination

Table 4.3

Experiment 2:

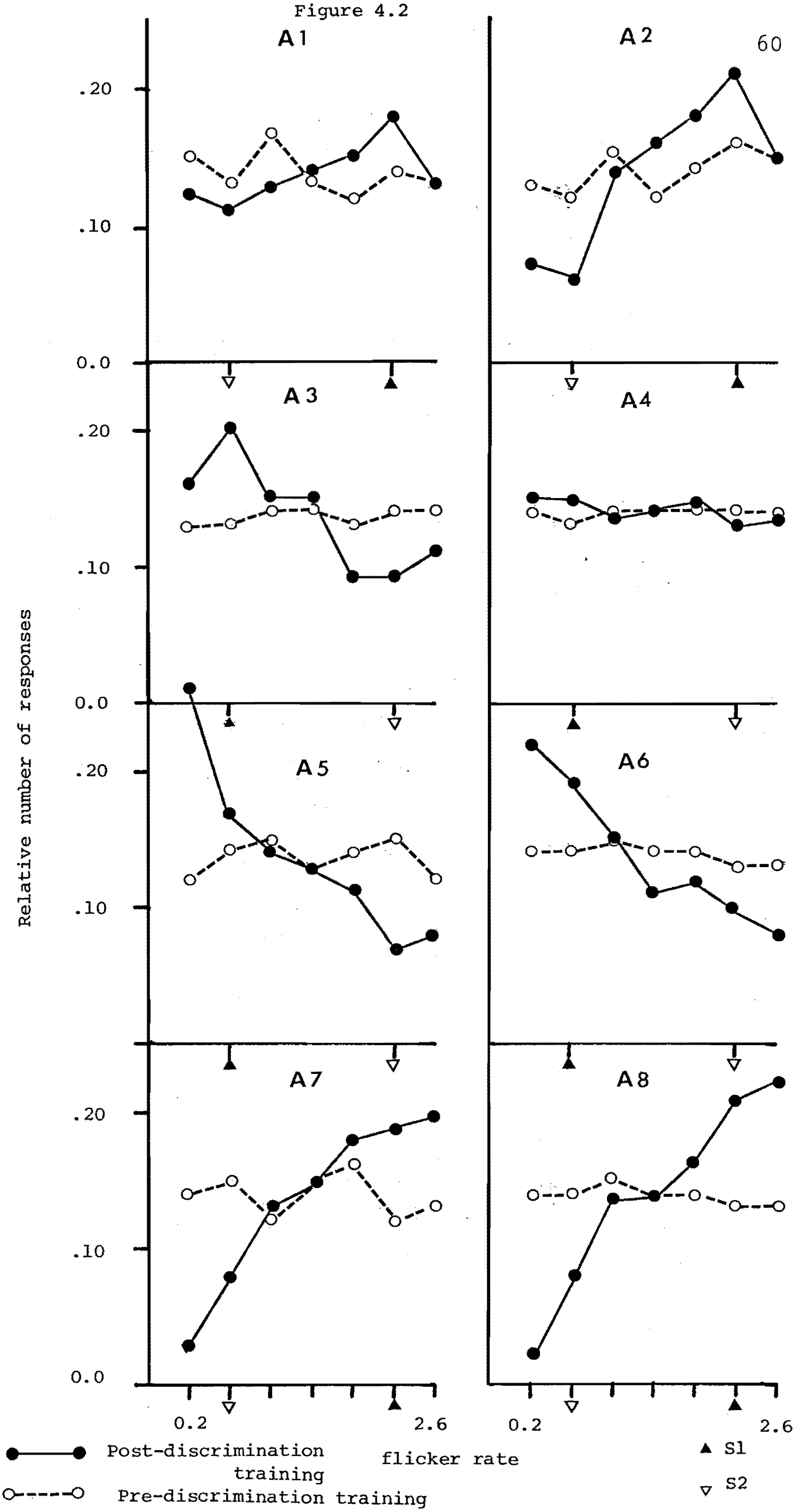
Discrimination indices for all subjects for the final six sessions of baseline and discrimination training.

Training Procedure	Subject	Baseline	Discrimination
SIG	A1	.47	.60
SIG	A2	.46	.71
SIG	A3	.50	.64
SIG	A4	.50	.52
EXT	A5	.48	.70
EXT	A6	.51	.66
EXT	A7	.51	.64
EXT	A8	.49	.71

Figure 4.2

Experiment 2: Pre- and post-discrimination training generalization gradients along the flicker rate dimension expressed as relative response rates for all subjects. Subjects A1 to A4 were trained on MULT VI-60sec VI-60sec(SIG) and subjects A5 to A8 on MULT VI-60sec EXT.

Figure 4.2


A1
A2
A3
A4
A5
A6
A7
A8
.20
.10
0.0
Relative number of responses
0.2
2.6
flicker rate
Post-discrimination training
Pre-discrimination training
S1
S2

training gradients were either flat (e.g. for subjects A3, A4, A6 and A8) or nonsystematic (e.g. A1, A7). This indicates that the stimulus dimension of flicker rate did not demonstrate inherent properties controlling differential responding, prior to the discrimination training.

A4, the subject which had failed to respond differentially to S1 and S2 during discrimination training, showed no evidence for acquired dimensional stimulus control along the flicker rate dimension. However, all the other subjects did show acquired dimensional stimulus control. All of the other three subjects trained in the SIG condition (A1, A2 and A3) showed maximal responding to S1 and minimal responding to S2. In contrast, all four subjects trained in EXT (A5-A8) produced peak shift in generalization testing, and three of these also showed negative peak shift. The minimal response rate of the fourth, A5, was to S2.

4. DISCUSSION

The results of Experiment 2 confirm those of Experiment 1, along a different stimulus dimension. The one exception to this is subject A4, which failed to develop any discrimination between the two training stimuli, and therefore produced flat generalization gradients. It appears from the results of the remaining seven subjects, that it is not the extent of response suppression per se that is the important factor in determining the development of sloping generalization gradients. In this experiment, the S2 response rate remained considerably greater than zero for all subjects. In fact, Figure 4.1 shows that there was virtually no response suppression at all for A1 or A6. Nevertheless, both produced clear dimensional stimulus control (fig. 3.2). The lack of relationship between the extent of contrast and of response suppression has relevance for theories of behavioural contrast which assume a constant output of responses (Smith and Hoy, 1954).

The comparison of results of the SIG and EXT groups in both Experiments 1 and 2 demonstrates that the covariation of contrast and peak shift does not apply for all methods of response suppression. The results of these two experiments also limit the generality of conclusions that could be drawn about the relationships among other features of responding within a discrimination procedure. As discussed above, there is no clear quantitative relationship between contrast and suppression. Although in all cases in Experiment 2, behavioural contrast preceded dimensional stimulus control, the occurrence of contrast cannot be taken to be a necessary condition for this dimensional control, because in Experiment 1, one subject (JI) showed no positive contrast but gave clear evidence for differential responding during later generalization testing.

There is also no indication from these results that response rates were determined by the rate of flicker, as would be expected within the framework of the stimulus intensity dynamism model (Hull, 1949; Blue, Sherman and Pierrel, 1971), which suggests that animals respond faster during stimuli that are more intense. Support for this model using discrimination paradigms similar to that reported has been contradictory. Sloane (1964) trained pigeons along a flicker rate dimension and reported that

> "Certain birds appear to have an innate tendency to respond more rapidly in the presence of faster rates of flicker" (p. 221)

Boakes (1972) reported the opposite. He tested dimensional stimulus control along a flicker rate dimension using pulse frequency of the houselight, and found that each subject produced inverted-U functions along this S2 dimension, but all showed a bias towards lower response rates in the presence of higher frequencies. Winton (1975) obtained peak shift following simultaneous discriminations and in all cases the maximal response rates were in the presence of stimuli of lowest intensity.

Therefore, to minimise the effects of a response bias in either direction, half the subjects in each group of Experiment 2 were assigned the faster flicker rate as S2.

Although positive behavioural contrast did occur during discrimination training in both Experiments 1 and 2, there was poorer differential responding during the latter, as can be seen by comparing the discrimination indices of Tables 3.2 and 4.3. One can only speculate as to why this is so, but it appears that flicker rate may be a more difficult discrimination for pigeons to make. Although there are reports of successful discrimination along this dimension (Boakes, 1972; Sloane, 1964, 1966; Winton, 1973, 1975), Winton (1973) also noted difficulties in establishing discrimination using flicker rate. With comparable procedures, the visual intensity discrimination was generally found to be easier than the flicker rate.

The EXT group results support those of Hanson (1959) in giving empirical support for Spence's theory of algebraic summation of excitatory and inhibitory gradients. The failure of the SIG group to demonstrate peak shift also cannot be ascribed to a methodological mishap as it has been confirmed along a second dimension. Neither could it be attributed to poor discrimination during the multiple schedule training because there was little difference between the D.I.s of the SIG and EXT groups in both Experiments 1 and 2. Thomas (1962) has indicated that this in itself would not prevent the occurrence of peak shift. He showed that peak shift still occurs following multiple schedule training where there is even only partial attainment of the discrimination.

Does this then mean that the SIG condition does not result in the development of inhibitory gradients around S2? On its own, the failure to produce peak shift is not an adequate basis for assuming there is no inhibitory process in operation (Mackintosh, 1974). A more direct test of the predicted difference between

EXT and SIG in terms of development of inhibition, must be made. This requires the use of an inter-dimensional discrimination procedure so that the gradients around S1 and S2 can be evaluated separately, rather than indirectly through their hypothesised interaction, as is the case following intradimensional training. The following series of experiments therefore deal with different training and testing procedures to see whether the differences between SIG and EXT obtained in Experiments 1 and 2 are followed by other differences in these two response suppression techniques.

CHAPTER V

EXPERIMENT 3

1. AIM

In this experiment, an interdimensional discrimination procedure was used in place of the intradimensional training of the first two experiments, to compare dimensional stimulus control around S1 and S2 following training with either EXT or SIG. This experiment was also used as a pilot study to evaluate the merits of using three kinds of generalization tests: testing in extinction (as in the first two experiments), combined cues testing in extinction, and testing using resistance to reinforcement. These procedures were investigated both in practical terms, e.g. ease of administration, and to examine the consistency with which dimensional stimulus control could be measured by several procedures.

(i) Interdimensional training

If responding is established in the presence of S1, other stimuli may control responding in proportion to their similarity to S1, giving an inverted U gradient with a maximum at S1. Similarly, it is reasonable to suppose that if some procedure were used to decrease the probability of responding in the presence of S2, then other stimuli would also suppress responding in proportion to their similarity to S2, producing a U-shaped gradient with a minimum at S2. The use of interdimensional discrimination training as a means of producing these separate gradients around S1 and S2 was developed by Jenkins and Harrison (1962) along an auditory frequency dimension, and Honig, Boneau, Burnstein and Pennypacker (1963) along a line orientation dimension. In Jenkins and Harrison's study, S^+ [i.e. S1 in the nomenclature of this series of experiments] was white noise and S^- [S2], a tone of 1000Hz. Generalization testing was conducted along the auditory frequency dimension and resulted in gradients with minima at S^-. Presumably, the different response rates to the stimuli reflect inhibitory dimensional control around S^- rather than any differential effect of S^+, which is equidistant from all auditory frequencies. Honig et al's procedure was parallel. They applied Guttman and Kalish's (1956) procedure with one group of subjects trained with S^+ [S1] as a black vertical line and S^- [S2], a blank white key. Testing along the line orientation dimension produced excitatory gradients around S^+. The next group of pigeons learnt the reverse discrimination, i.e. S^- was the line and S^+ the blank key. This procedure, like Jenkins and Harrison's, produced U-shaped gradients with minima at S^-, although the absolute number of responses made by this group was less than by the group tested on the dimension around S^+.

In both these cases, the training procedure was a

MULT VI EXT schedule. Other schedules have also been shown to produce U-shaped (inhibitory) gradients around S2. Weisman (1969, 1970) has demonstrated this using a longer VI schedule, DRL and DRO in place of EXT, procedures which also produce behavioural contrast and peak shift after intradimensional training. Rilling, Caplan, Howard and Brown (1975) obtained U-shaped gradients following errorless discrimination learning.

The dimensions along which such U-shaped gradients have been found include those of auditory frequency (Jenkins and Harrison, 1962; Westbrook, 1973; and Klein and Rilling, 1974 , who trained pigeons in a treadle press response instead of the more traditional key-peck), flicker rate (Boakes, 1972), and wavelength (Dawley and Denny, 1974; Friedman and Guttman, 1965; Karpicke and Hearst, 1975; Lyons and Thomas, 1967). The majority of studies have used the line orientation dimension, including Baron and Bresnahan (1969), Couch (1975), Davis (1971), Farthing and Hearst (1968), Halliday and Boakes (1972), Hearst, Besley and Farthing (1970), Honig and Beale (1976), Newman and Baron (1965), Parker (1973), Richards (1974), Rilling, Caplan, Howard and Brown (1975), Weisman (1969), Weisman and Palmer (1969), Wilkie (1974), Yarczower (1970), Yarczower and Curto (1972), Yarczower and Evans (1974), and Zentall, Collins and Hearst (1971).

(ii) Types of generalization tests

The interpretation of gradients around S2 following interdimensional training has paralleled that of S1 gradients. In the latter, a peaked gradient is said to demonstrate excitatory dimensional control around S1, or a flat gradient to demonstrate the absence of dimensional control. Terrace, 1966(b) stated that:

> "a U-shaped gradient, with a minimum at S^- [S2] would indicate that S^- was an inhibitory stimulus, while a flat gradient would indicate the absence of any inhibitory function". (p. 1678)

Deutsch (1967) and Hearst, Besley and Farthing (1970) argued that there may be other accounts for flat gradients such as a "floor effect" preventing the detection of differential responding along the dimension because all response rates were very low. Hearst et al (1970) and Hearst (1972) proposed two additional generalization test procedures designed to elevate response rates and thus demonstrate dimensional control around S2. The first of these is the combined-cues procedure which involves simultaneous presentation of test stimuli along the dimension around S2 with S1. Because S1 already controls a higher rate of responding than S2, its presence would also result in a higher response rate than would occur in the presence of S2 alone. By raising the overall response rate above zero, differential responding and therefore dimensional control of responding can be evaluated. Apart from Hearst et al (1970), several experimenters have used this combined-cues procedure, the classical conditioning equivalent of which was reported by Reberg and Black (1969). Davis (1971), Richards (1975), Rilling, Caplan, Howard and Brown (1975), Wiltz, Boren, Moerschbaecher, Creed and Schrot (1973, 1974), Yarczower (1970), Yarczower and Curto (1972), and Yarczower and Evans (1974) have all used the procedure although with varying degrees of success in demonstrating inhibitory dimensional stimulus control.

The second additional generalization test procedure outlined in Hearst et al's (1970) monograph is the resistance-to-reinforcement technique. All test responses are reinforced on the same schedule of reinforcement, instead of the usual testing in extinction. The underlying assumption is that conditioning is retarded by the presence of an inhibitory stimulus, and that the different amounts of inhibition developed through training will result in U-shaped gradients around S2. This procedure has been used by Rilling, Caplan, Howard and Brown (1975), Karpicke and Hearst (1975), Wilkie and Masson (1976), and Zentall, Collins and Hearst (1971).

Hearst, Besley and Farthing (1970) advocated the use of the combined-cues and resistance-to-reinforcement testing procedures because of the inadequacies of drawing conclusions about the presence or absence of inhibitory dimensional stimulus control from generalization testing in extinction. The use of different criteria for deciding whether or not a stimulus is inhibitory has caused much conflict in the interpretation of experimental results. Therefore in Experiment 3 and subsequent experiments, all three procedures were used and the results compared.

2. METHOD

This was as outlined in the General Method with the following specific characteristics:

(i) Subjects:

B1 to B8

(ii) Procedure:

a. Preliminary training

During the initial stages of key-peck acquisition, the key was illuminated with a red light with a brightness of two lux.

b. Baseline training

Whereas in the first two experiments the baseline training procedure was a two-ply multiple schedule, in this experiment baseline training consisted of single-stimulus training. Each daily session comprised 30 one-minute presentations of the training stimulus which was a yellow response key. The colouration was obtained by introducing a yellow cellophane slide into the light path from the projector. The illumination of this yellow key was set at 16 lux. There were sixteen days of single stimulus training on a VI-60sec schedule.

c. Pre-discrimination training generalization test

Eight stimuli were presented during this test. One was the yellow key of the single stimulus training, and the remaining seven were orientation of a black line on a white background: 0° (horizontal), 15°, 30°, 45°, 60°, 75°, and 90° (vertical) respectively.

d. Discrimination training (Part I)

For half the subjects (B1 to B4) discrimination training comprised MULT VI-60sec VI-60sec (SIG), and for the other half (B5 to B8) it comprised a MULT VI-60sec EXT schedule. The two training stimuli were

yellow key	S1 for all subjects (i.e. VI-60sec)
45° line	S2 for all subjects (i.e. VI-60sec(SIG) or EXT)

e. Post-discrimination training generalization test

The same testing procedure was followed as for the generalization test prior to discrimination training, i.e. both tests were conducted in extinction for all subjects.

f. Discrimination training (Part II)

Following this test, the original discrimination training procedure was reinstated for a further three sessions.

g. Combined-cues generalization tests

The next step was a series of two combined-cues generalization tests, which followed a procedure outlined by Hearst, Besley and Farthing (1970) and Davis (1971). In one test session, the eight test stimuli were the blank yellow key and the seven line orientations as before, but in this test the lines were superimposed not on a white background, but on the yellow background, giving each slide a brightness of 12 lux. In the other test session, the procedure was the same except that the yellow key and yellow background of the line orientations had been replaced by a novel stimulus, viz. a green key with a brightness of 8 lux. The order of testing is given in table 5.1.

h. Discrimination training (Part III)

Again the discrimination training procedure was reinstated for a further four days.

i. Resistance-to reinforcement generalization tests

This series of nine generalization tests conducted on successive days involved the use of the technique developed and described by Hearst, Besley and Farthing (1970). The basic procedure followed the format of the post-discrimination training generalization test in extinction. However, the difference was that during the test proper, responding was reinforced on a VI-60sec schedule in the presence of each stimulus. The signal for reinforcement availability was not operative during the test.

Table 5.1

EXPERIMENT 3:

Combined-cues procedure: order of generalization testing using either S1 (i.e. a yellow background) or a novel stimulus (i.e. a green background) superimposed on the test stimuli.

Subject	Test session 1	Test session 2
B1	yellow	green
B2	green	yellow
B3	green	yellow
B4	yellow	green
B5	green	yellow
B6	yellow	green
B7	yellow	green
B8	green	yellow

j. Discrimination training (Part IV)

Again, the next step was a return to the discrimination training procedure. B1 to B4 remained on a MULT VI-60sec VI-60sec(SIG) schedule, and B5 to B8 on a MULT VI-60sec EXT schedule. However, for all subjects there was one modification to the original training procedure: the S1 stimulus was changed from a blank yellow to a blank white key (30 lux). S2 remained as the 45° black line on a white background.

k. Second generalization test in extinction

A finer grain of analysis was sought in the second generalization test in extinction. There were eight test stimuli: S1 (i.e. a blank white key), and seven orientations of a black line on a white background, one of which was S2 (i.e. a 45° line). In this test the orientation of the test stimulus lines differed by only 5°, not 15° as in the preceding generalization tests. The test stimuli therefore were:

1. Blank key
2. 30° black line on a white background
3. 35° " " " " " "
4. 40° " " " " " "
5. 45° " " " " " "
6. 50° " " " " " "
7. 55° " " " " " "
8. 60° " " " " " "

In all other respects the procedure for this test was identical to that of the first post-discrimination training generalization test.

3. RESULTS

(i) Baseline and discrimination training (Part I)

Figure 5.1 shows the individual data on all subjects during the discrimination training (part I). The data are presented as actual response rates (viz. responses per minute) rather than as normalised response rates as it is not possible to present S2 data as normalised rates following single-stimulus training on S1. The mean response rate for the last six sessions of baseline (VI-60sec) training is also shown. Figure 5.1 shows clear evidence for positive behavioural contrast in all subjects in both the SIG and EXT groups. There is a considerable range of response suppression exhibited, as can be seen from both the graphs and the discrimination indices (Table 5.2).

(ii) Generalization testing

Figure 5.2 shows the relative response rates of all subjects during the post-discrimination training generalization test in extinction. Overall, the response rates are low along the line orientation dimension, and show no clear cut dimensional stimulus control. (For results of pre-discrimination training generalization test, see Appendix III, P. 205)

(iii) Combined-cues generalization tests

The results of the combined-cues generalization test are shown in Figure 5.3, and again fail to indicate consistent dimensional stimulus control,

Figure 5.1

Experiment 3: Response rates of all subjects to S1 and S2 during discrimination training (part I). The horizontal black line represents the mean response rate for the final six sessions of baseline (VI-60sec) training to S1.

Figure 5.1

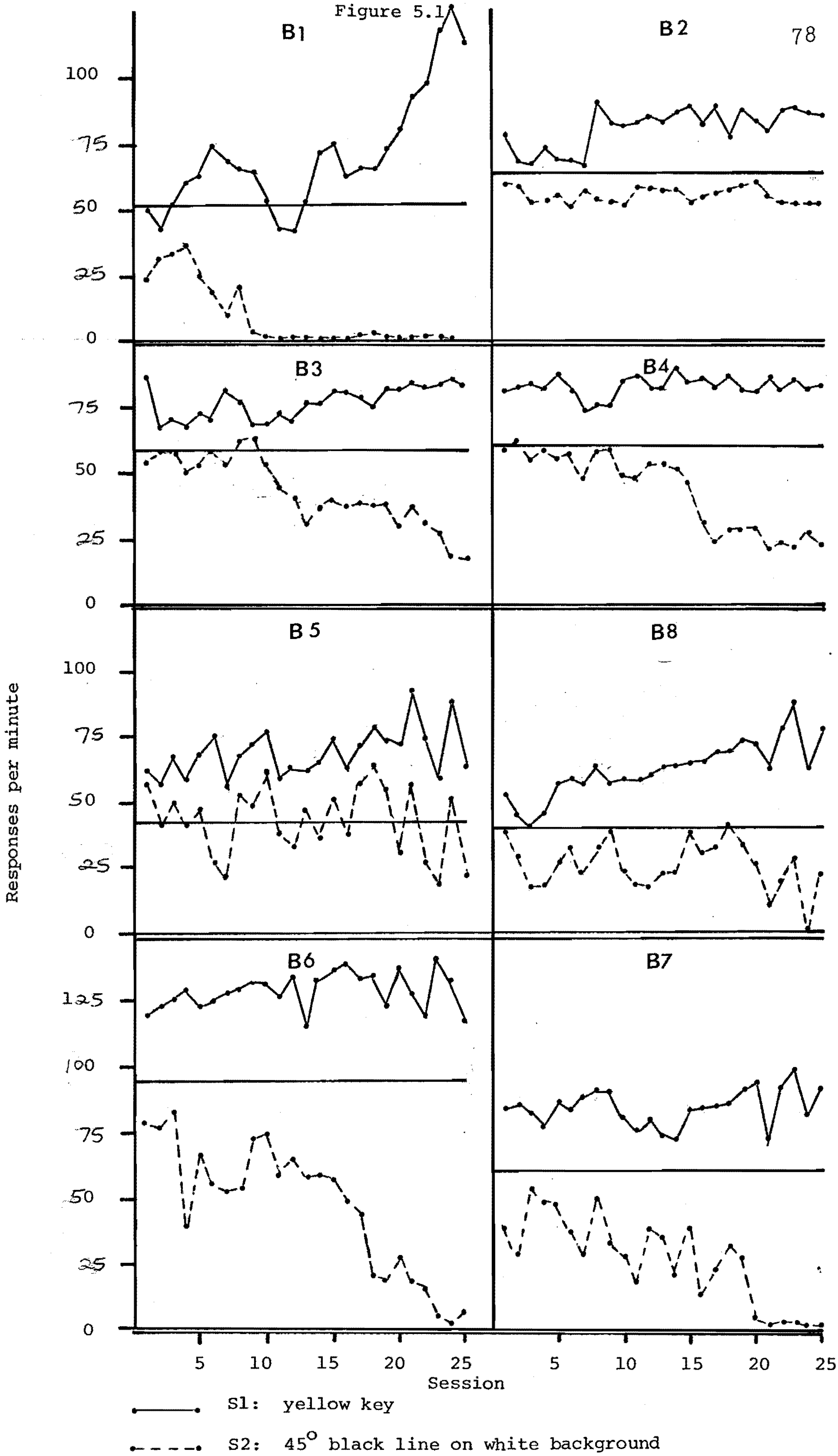

B1
B2
B3
B4
B5
B8
B6
B7
Responses per minute
100
75
50
25
0
125
Session
5
10
15
20
25
S1: yellow key
S2: 45° black line on white background

Table 5.2

EXPERIMENT 3:

Discrimination indices for all subjects for the final six sessions of discrimination training (part I).

$$D.I. = \frac{S1}{S1 + S2}$$

where S1 and S2 represent response rates in each component.

SIG group		EXT group	
Subject	D.I.	Subject	D.I.
B1	0.99	B5	0.68
B2	0.61	B6	0.91
B3	0.76	B7	0.99
B4	0.78	B8	0.79

Figure 5.2

Experiment 3: Relative response rates during the post-discrimination training generalization test in extinction along the line orientation dimension around S2 (45° black line on white background), including responses to S1 (yellow key).

Figure 5.2

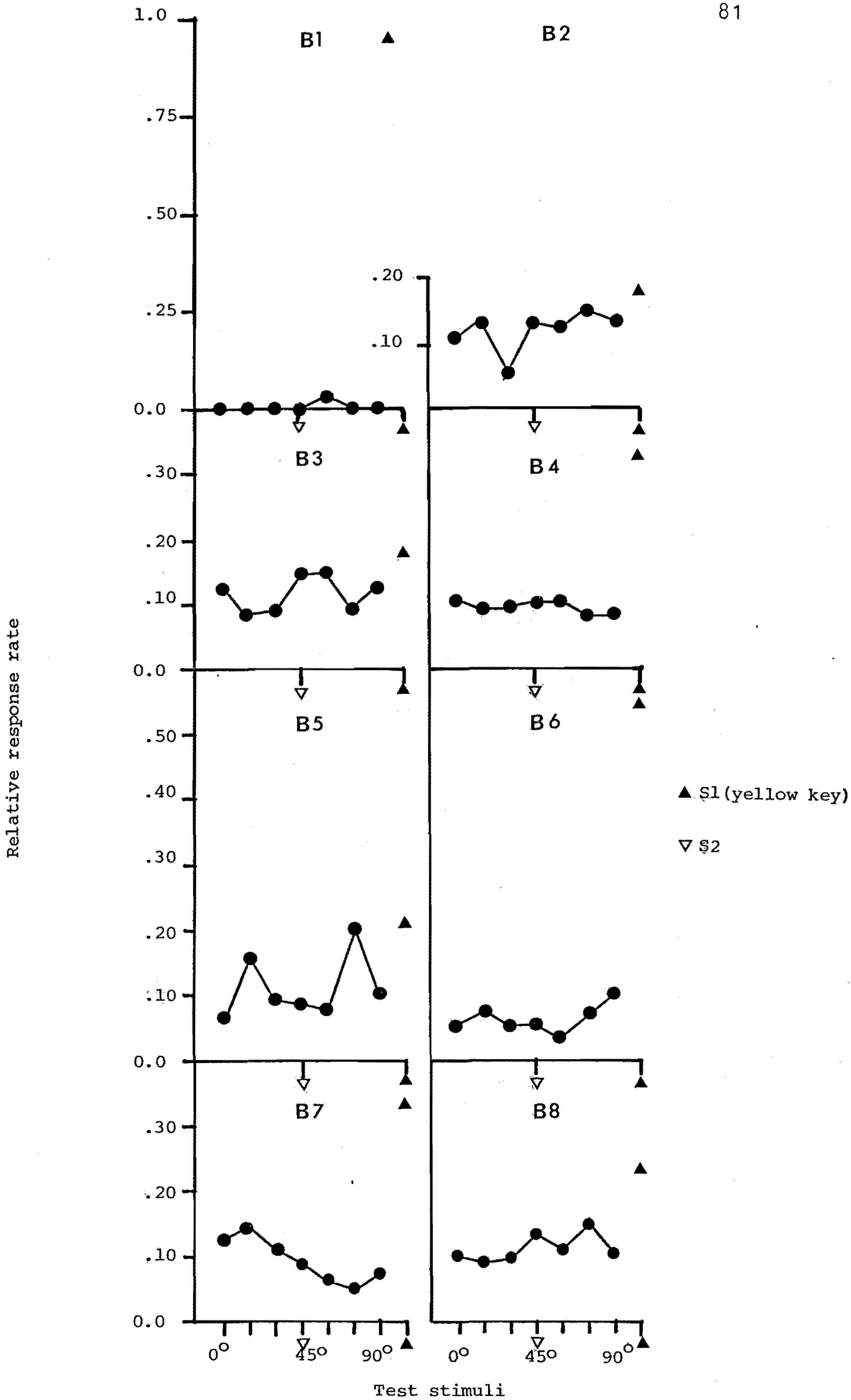

B1
B2
B3
B4
B5
B6
B7
B8
1.0
.75
.50
.25
0.0
.20
.10
.30
.40
Relative response rate
0°
45°
90°
Test stimuli
▲ S1 (yellow key)
▽ S2

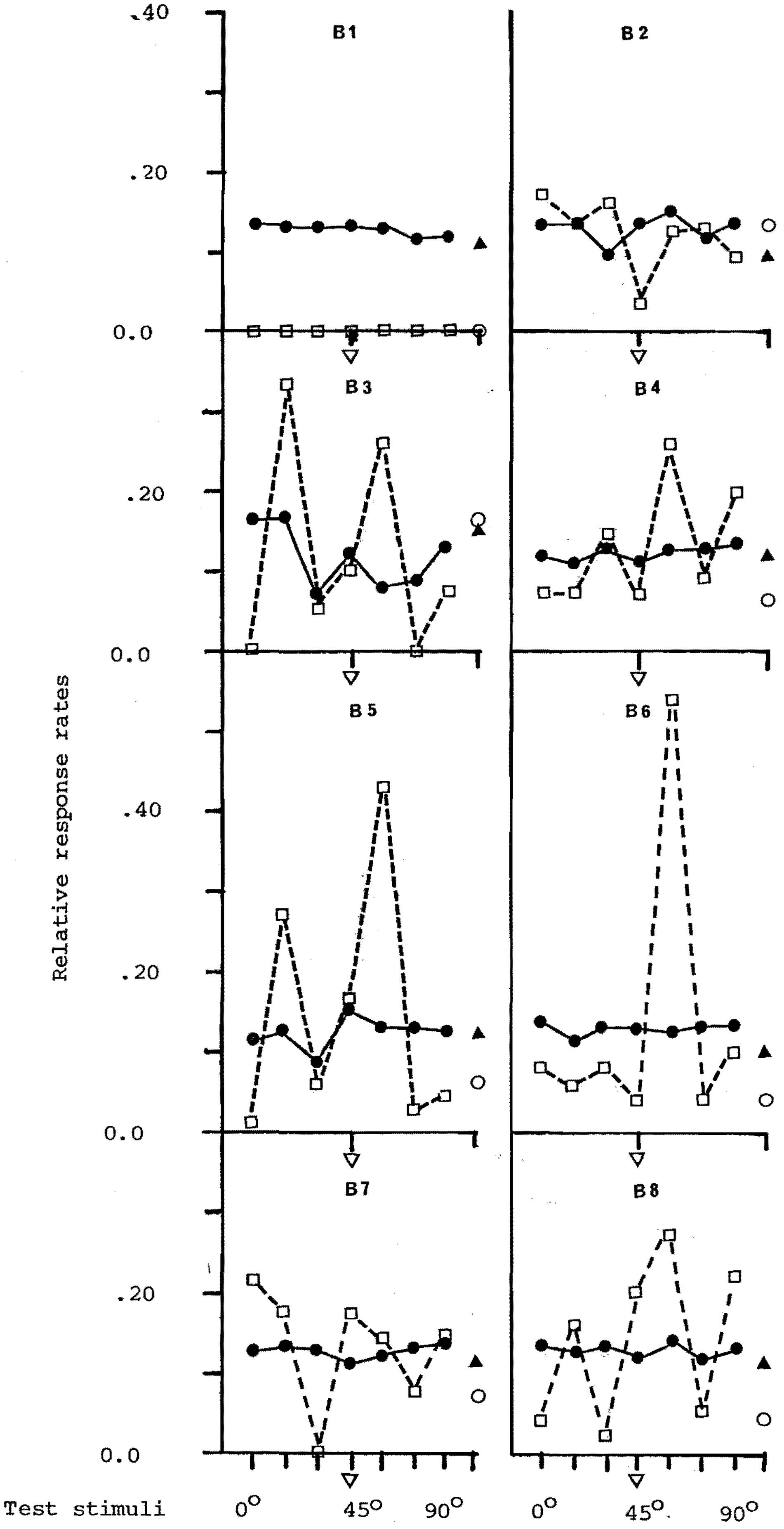
Figure 5.3

Experiment 3: Combined-cues generalization tests - relative response rates of each subject on two combined-cues tests along the line orientation dimension:

a. with a yellow background

b. with a green background

Figure 5.3



black line on yellow background

black line on green background

▲ Responses to yellow key alone

▽ S2 (45° black line)

○ Responses to green key alone

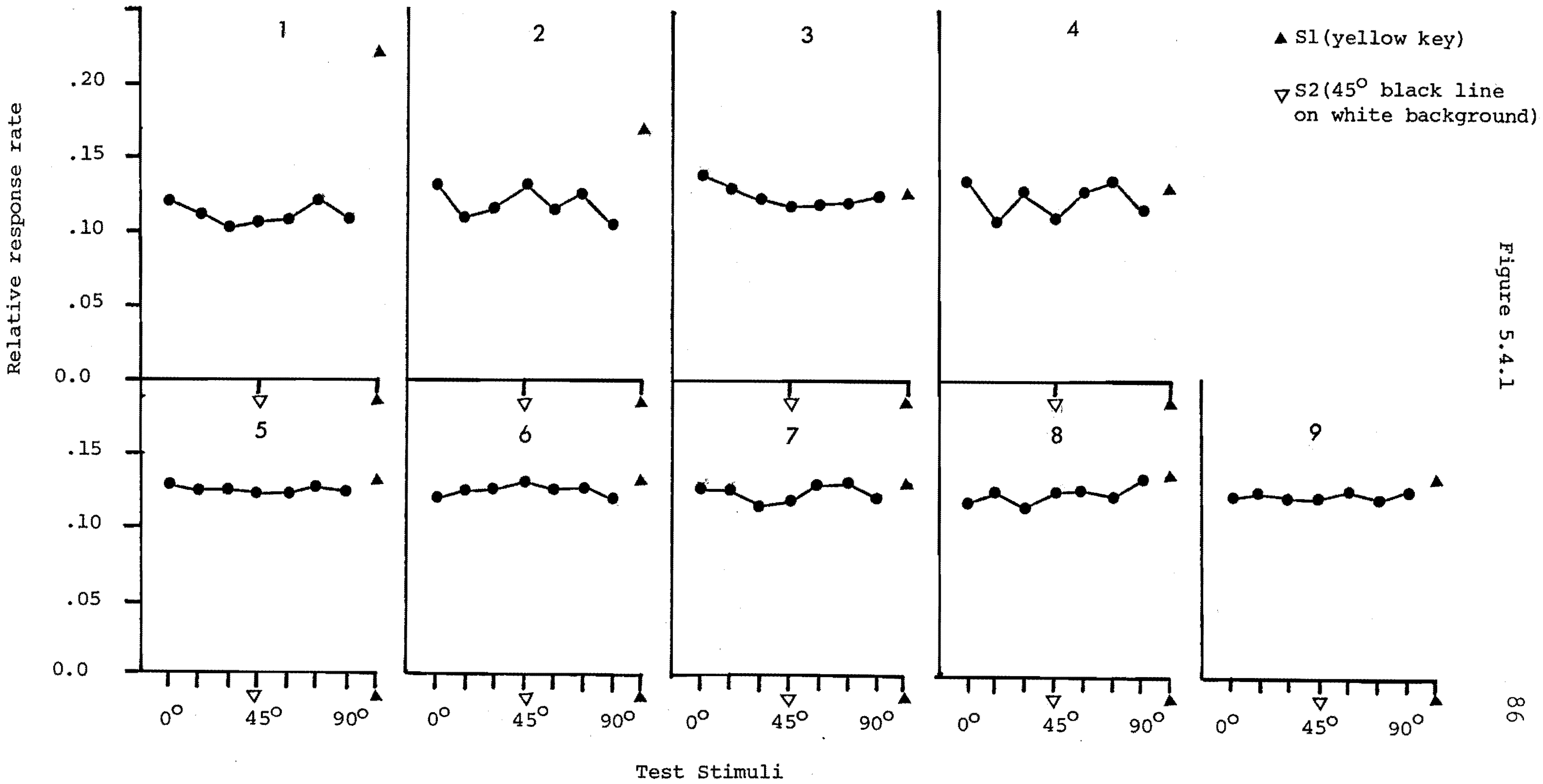
particularly during testing with S1 as the added stimulus. However, the gradients are quite different from those obtained during the first generalization tests: in these, very few responses were made to any of the line orientations while the response rate to S1 was high. In both combined-cues tests, response rates to the cue-plus-line compounds were higher than during the first test, comparable with those to S1 alone. The one exception to this was the zero rate of responding of B1 throughout the whole test in the presence of the novel stimulus (green). If there were no differential responding, the relative rates to each stimulus would have been about 0.125. Response rates in the presence of the superimposed S1 reflect this. However, the response rates in the presence of the novel stimulus show considerable variability (with the exception of B1). There is no evidence of systematic dimensional stimulus control. Nevertheless, a trend in the relative response rates can be seen: subjects B3, B4, B5, B6 and B8 all had high response rates to the combined stimulus of the 60^{o} line on a green background, and B3, B5 and B8 had an additional peak at the 15^{o} line on a green background. This strongly suggests that some artifactual process had evolved to produce such a clear pattern in so many subjects, but the actual nature of it is unknown, as it did not appear on any other generalization tests.

(iv) Resistance-to reinforcement tests

The grouped data shown in Figures 5.4.1 and 5.4.2

Figure 5.4.1

Experiment 3: Resistance-to-reinforcement generalization tests - grouped relative response rates of subjects B1 to B4 over 9 successive days' testing.

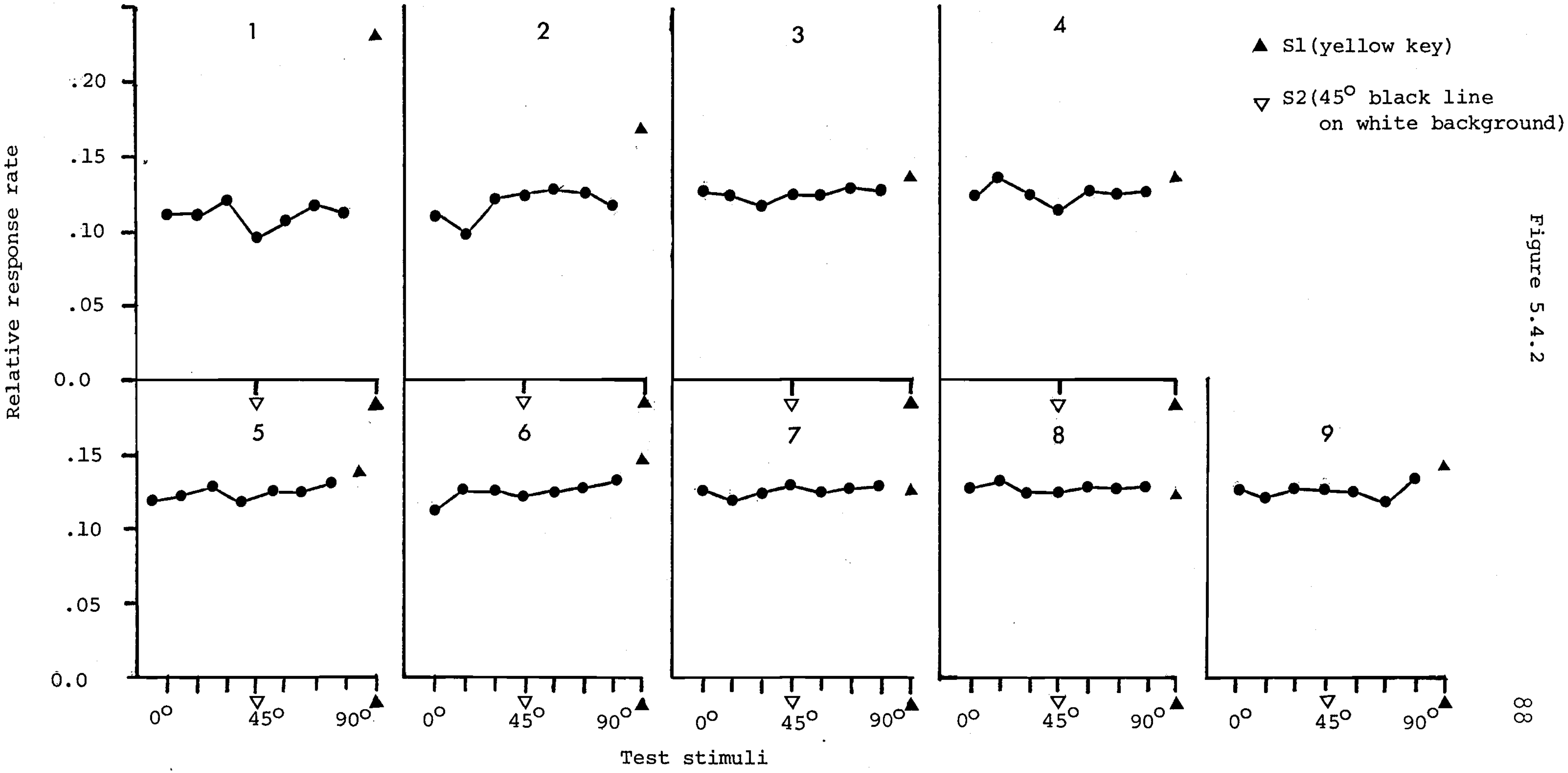


1
2
3
4
5
6
7
8
9
S1(yellow key)
S2(45° black line on white background)
Relative response rate
.20
.15
.10
.05
0.0
0°
45°
90°
Test Stimuli

Figure 5.4.1

Figure 5.4.2

Experiment 3: Resistance-to-reinforcement generalization tests - grouped relative response rates of subjects B5 to B8 over 9 successive days' training.



1
2
3
4
5
6
7
8
9
.20
.15
.10
.05
0.0
Relative response rate
0°
45°
90°
Test stimuli
S1(yellow key)
S2(45° black line on white background)

Figure 5.4.2

give a good representation of the gradients obtained from individual subjects in each group. There is obviously no evidence of dimensional stimulus control along the line orientation dimension, nor any evidence of changes in either the occurrence of dimensional control, or absolute response rates, over the nine sessions of testing. This is not due to masking of individual trends by grouping the data: individual relative response rates were substantially the same as those shown in Figures 5.4.1 and 5.4.2 (see Appendix III).

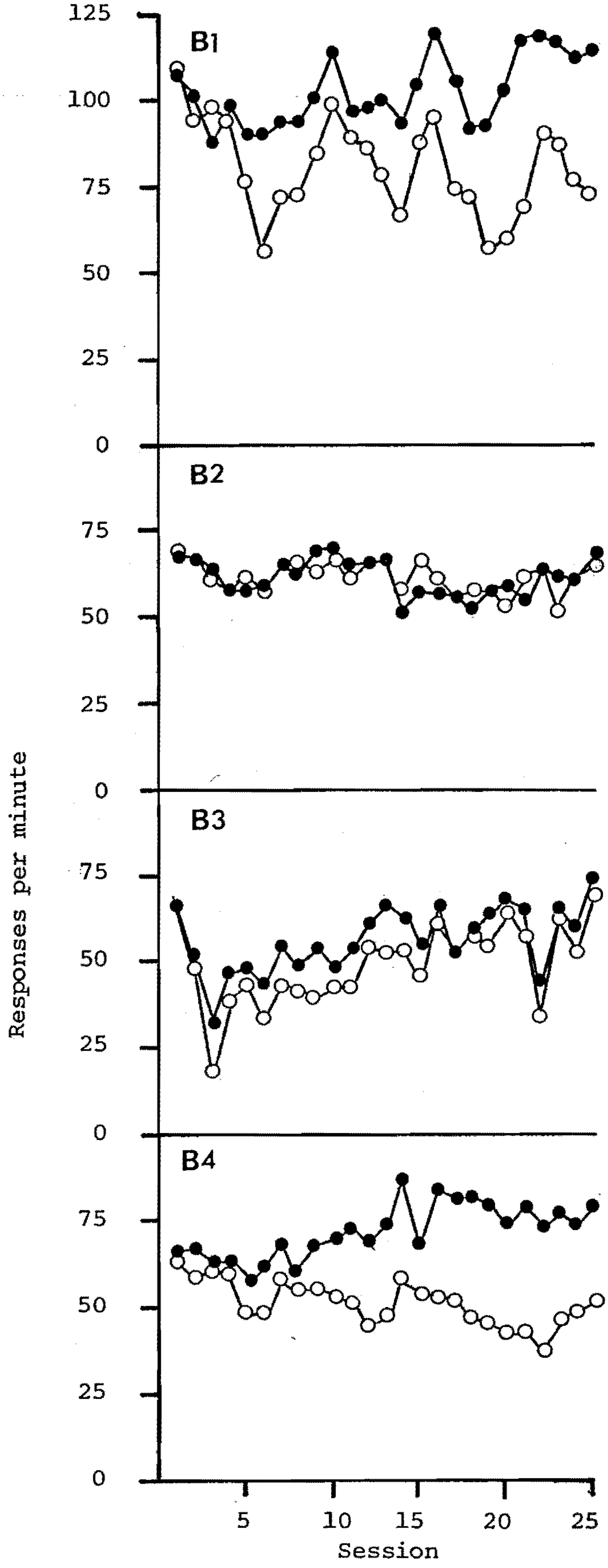
(v) Discrimination training Part (IV)

The response rates during the discrimination training with S1 as a blank white key are shown in Figures 5.5.1 and 5.5.2. The level of discrimination achieved by the SIG group subjects is lower than during the original discrimination training where S1 was a yellow key, but is about the same for the EXT group (refer to Figure 5.1). One of the SIG subjects, B2, failed to learn this discrimination. This subject had also shown no response suppression in S2 on the original discrimination, but had produced positive contrast. Another SIG subject, B3, showed very little difference in response rates but the higher response rate was always to S1. The inability of this group to develop a greater degree of differential responding suggests that the extended prior history of unsignalled reinforcement to all stimuli during the resistance-to-reinforcement tests interfered with their ability to

Figure 5.5.1

Experiment 3: Discrimination training (part IV) - individual response rates in both components during MULT VI-60sec VI-60sec(SIG) with S1 as a blank white key and S2 as a 45^{o} black line on a white background.

Figure 5.5.1



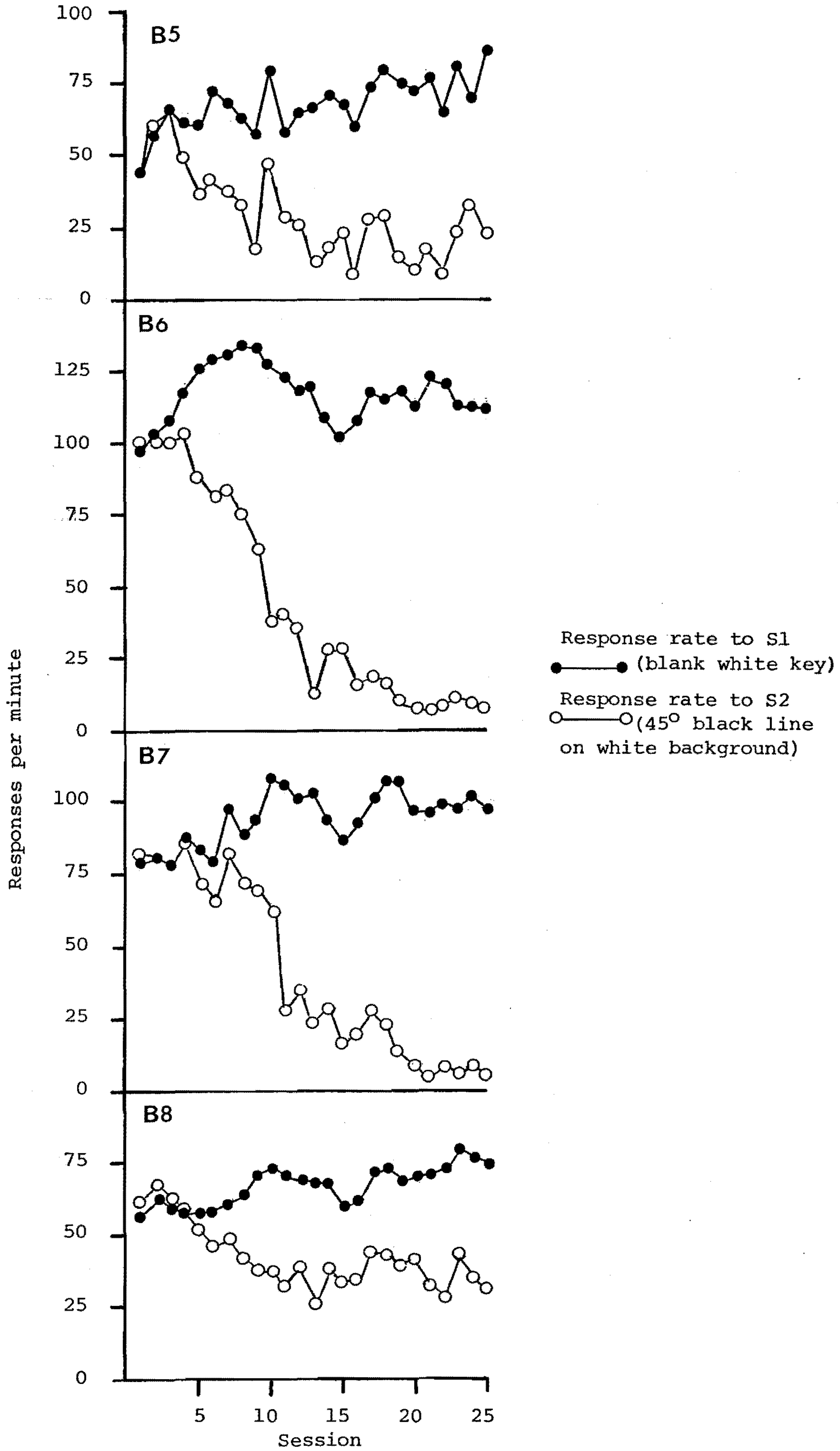
Response rate to S1 (blank white key)

Response rate to S2 (45° black line on white background)

Figure 5.5.2

Experiment 3: Discrimination training (part IV) - individual response rates in both components during MULT VI-60sec EXT with S1 as a blank white key and S2 as a 45^{o} black line on a white background.

Figure 5.5.2


B5
B6
B7
B8
100
75
50
25
0
125
Responses per minute
5
10
15
20
25
Session
Response rate to S1
(blank white key)
Response rate to S2
(45° black line
on white background)

attend to the signal when it was reinstated.

The discrimination indices of the final six sessions of this phase are given in Table 5.3.

(vi) Second generalization test in Extinction

As in all the other generalization tests conducted in this experiment, the results of this final generalization test failed to demonstrate dimensional control (see Figure 5.6).

4. DISCUSSION

(i) Discrimination training

This experiment compared testing in extinction, combined-cues and resistance-to-reinforcement tests following interdimensional training in which S2 was corelated with either EXT or SIG. The discrimination training data of Figure 5.1 confirm the results of Experiments 1 and 2, i.e. the occurrence of behavioural contrast in all subjects, but with varying degrees of response suppression in S2. One subject in each of the two groups, viz. B2 and B5, showed little suppresion. In contrast, B1, B7 and B8 developed suppression approaching a zero response rate in S2 which had not been reached by subjects in the first two experiments and may well reflect the absence of prior excitatory training in the presence of that stimulus during a baseline phase. This explanation appears most likely in view of the response rates obtained during Discrimination Training Part IV, (Figures 5.5.1 and 5.5.2),

Table 5.3

EXPERIMENT 3:

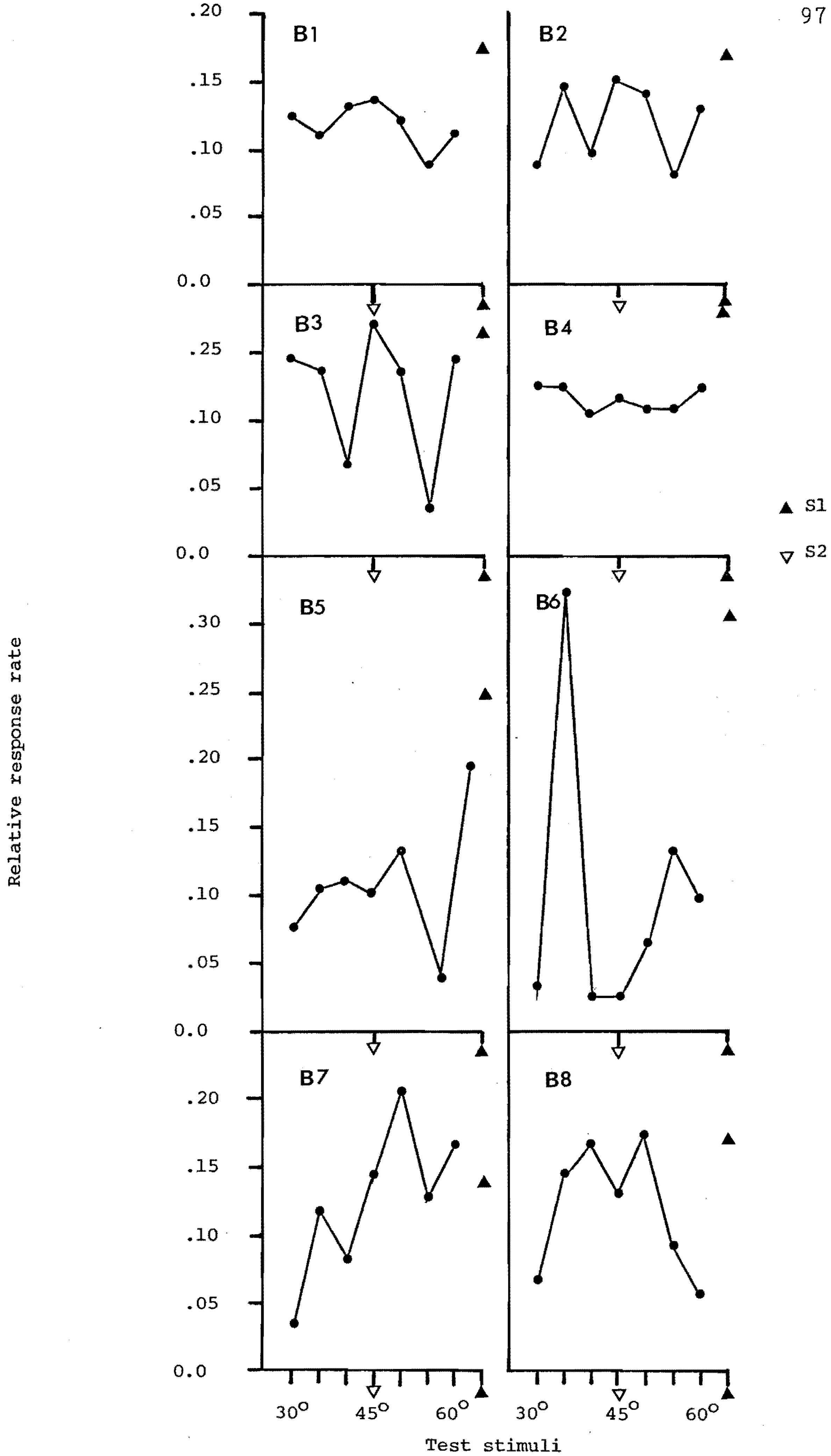
Discrimination indices (D.I.) for all subjects for the final six sessions of discrimination training (part IV).

SIG group		EXT group	
Subject	D.I.	Subject	D.I.
B1	0.62	B5	0.75
B2	0.52	B6	0.93
B3	0.52	B7	0.85
B4	0.61	B8	0.72

Figure 5.6

Experiment 3: Relative response rates of all subjects during second generalization test in extinction along the line orientation dimension using a finer grain of analysis. The test stimuli are 8 black lines on a white background, from 30° to 60° differing by 5° only. S1 is a blank white key.

Figure 5.6


B1
B2
B3
B4
B5
B6
B7
B8
.20
.15
.10
.05
0.0
.25
.30
S1
S2
Relative response rate
30°
45°
60°
Test stimuli

which followed the resistance-to-reinforcement tests during which S1 and S2, along with the other test stimuli, were associated with a VI-60sec schedule of reinforcement. During this phase, only two subjects, B6 and B7, showed good evidence for divergence of response rates between S1 and S2. B2 showed no difference, and the rest did respond less to S2 than to S1, but the difference was minimal and the rates covaried. Without a baseline phase prior to discrimination training part IV, there can be no assessment of behavioural contrast.

(ii) Generalization testing

None of the generalization tests gave any evidence for dimensional stimulus control around S2, for either the SIG or the EXT groups. According to Terrace (1966b) this indicates the "absence of any inhibitory function". The results obtained in Experiment 1 and 2 are inconsistent with this conclusion because in these experiments S2 showed clear evidence of controlling lower rates of responding than S1 both during training and during later testing. Neither is it consistent with the findings of Farthing and Hearst (1968), who used a similar procedure and obtained reliable U-shaped gradients around S2 after MULT VI-60sec EXT after four or more sessions of training. One difference between the procedure adopted by Farthing and Hearst and that of Experiment 3 was in duration of stimulus presentation during testing: 30 sec in the former and 1 min in the latter. But in both cases this duration of stimulus presentation was the same as that in force during the prior discrimination training. Therefore methodological problems must be investigated as a reason for not producing evidence for dimensional stimulus control before it can be concluded that the flat gradients obtained reflect the absence of any such generalization.

One suggested explanation for the lack of inhibitory dimensional control demonstrated during Experiment 3 was that the test stimuli used provided too coarse a grain of analysis, and that dimensional control might therefore be demonstrated using more similar stimuli. However, as Figure 5.6 shows, this provided no further evidence of dimensional control than the other testing procedures. Unfortunately though, the comparability of the first and second generalization tests in extinction is limited because the subjects showed much poorer discrimination during Discrimination Training Part IV.

Some consolation is provided by evidence that other researchers have also found inhibitory gradients notoriously difficult to obtain, and usually flatter (i.e. exerting less dimensional control) than corresponding excitatory gradients around an S1. Halliday and Boakes (1972) compared the gradients obtained after training with freely available reinforcers and EXT. Only one subject, in the EXT group, produced an inhibitory gradient. Richards (1974) found that increasing the magnitude of the reinforcer and delaying its presentation resulted in flatter U-shaped gradients. There is no reason to suppose such a parameter was relevant in the present study, however. Studies such as that of Halliday and Boakes (1972) do imply that the U-shaped gradients around S2 are not as robust a phenomenon as the reverse gradients around S1. Boakes (1972) was explicit about these difficulties, referring specifically to the line orientation dimension:

> "Though many gradients using this dimension have been published, personal communications to the author suggest that there have been many unaccountable failures to obtain regular functions with this dimension". (p. 249)

(iii) Combined-cues test

This procedure was the one Hearst, Besley and Farthing (1970) were least optimistic about in terms of its future utility as a measure of inhibitory dimensional stimulus control. They listed as its disadvantages, the difficulty in ensuring strict orthogonality of S1 and S2, the effects of cue-redundancy in reducing the subject's attention to features of S2, and the fact that this redundancy would result in a simple discrimination made virtually without errors (p. 392). The only two experiments they had knowledge of that had used this technique, viz. Lyons (1969a) and Yarczower (1970), did not achieve the main objective of the technique which is to increase substantially the response rates to the combined stimuli so that differential responding along the S2 dimension could be demonstrated. Other experimenters since then have also failed to demonstrate inhibitory stimulus control using combined stimuli during extinction, even though the response rate to the combined S1-S2 stimulus is less than that to S1 alone. Davis (1971), Yarczower and Curto (1972) and Rilling, Caplan, Howard and Brown (1975) obtained such results using the dimension of line orientation, graphically supporting the Hearst, Besley and Farthing (1970) discrimination between conditional inhibition and inhibitory dimensional control, and showing that flat gradients, especially with low response rates, are an equivocal outcome. Such results suggest that the combined-cues procedure is least likely to produce a fruitful outcome in the pursuit of dimensional stimulus control and therefore was not incorporated into the remaining experiments in this series.

(iv) <u>Resistance-to-reinforcement tests</u>

Studies using this procedure have had clearer results. Rilling et al (1975) concluded it was a more sensitive measure of inhibitory stimulus control than the combined-cues procedure, and this was also shown by Karpicke and Hearst (1975) who, like Rilling et al (1975) used it following errorless discrimination training. Wilkie and Masson (1976) showed the effectiveness of the procedure in elucidating areas otherwise unknown. The dimensional control obtained using the resistance-to-reinforcement technique showed that their pigeons had attended to form as well as to colour although they had not responded to form during a generalization test in extinction. There has not been strong confirmation of Hearst et al's (1970) "flop-over" phenomenon (p. 395), an inversion of gradient shape in more than 70% of their subjects, possibly because other researchers perform fewer resistance-to-reinforcement tests (e.g. Zentall, Collins and Hearst (1971) who gave only three tests). Hearst et al (1970) reported that the "flop-over" appeared after five to ten sessions.

There are several possible reasons why, in Experiment 3, generalization testing failed to demonstrate dimensional stimulus control around S2. The first, that reducing the response rate to S2 did not result in dimensional control, is unlikely in view of the results of the first two experiments, and those of other researchers. A second possibility is one raised by Deutsch (1969), that the inhibitory learning is so strong that it generalizes completely to all stimuli. If so, even techniques designed to raise the overall response rate, such as the resistance-to-reinforcement tests, would not alter the flat gradient. But there is no test of dimensional control that could differentiate between flat gradients resulting from no dimensional control and those resulting from "too much", so this account must be given low priority.

Other explanations for the absence of dimensional control involve methodological problems, i.e. failure to measure an effect that was present. The flat gradients may indicate a floor effect, as discussed by Hearst et al (1970), Farthing and Hearst (1970), and Zentall (1972). Against this though is the failure to demonstrate differential responses along the test dimension even when response rates were raised in the resistance-to-reinforcement tests. A more likely avenue to take is to investigate the possibility that the controlling aspects of the stimuli were not those that were experimentally evaluated. There is evidence from several areas that subject and experimenter do not always agree on what are the relevant stimuli. The work on mirror-image reversal in studies of line orientation demonstrates this. Corballis and Beale (1970) showed that the discrimination appeared to be between the upper and lower parts of the key, rather than the orientation per se. (To avoid such a confounding of stimuli, all experiments in this series dealt with only a 90° range of line orientations, thereby ensuring that all test stimuli lay within the same two quadrants of the key.)

Stimulus control by the line may not have been essential for the acquisition of the discrimination. The discrimination may have been along the wavelength dimension: S1 was "yellow", S2 was "black and white". We know there are innate differences in species' preference for stimuli, and that pigeons are more likely than rats, for instance, to respond to the wavelength of the stimulus. This implies that other aspects of the experimental situation may have overshadowed the experimenter-intended discrimination. Newman and Baron (1965) trained pigeons on a discrimination including a vertical line on a green background, and testing produced a relatively constant response rate to different line orientations on green. Further testing may have revealed dimensional control, as Freeman and Thomas (1967) found in what was essentially a replication. They too got flat gradients of lines on a green background, but did get sloping gradients when they repeated the test using a black background. Overshadowing of one aspect of a stimulus by another during training may not require the explicit use of a compound stimulus. Again, this leads to the point that there is no guarantee that the feature varied by the experiment has gained control over the responses of the subject. Boneau and Honig (1964) obtained relatively flat gradients testing along the line orientation dimension after a discrimination between the presence and absence of a vertical line. These results are similar to those of Experiment 3.

These considerations suggested appropriate changes to the stimuli used in the next study. Instead of teaching a discrimination between "yellow" and "black and white", S1 in Experiment 4 was changed to a blank white key in an effort to eliminate wavelength as a controlling stimulus. The salience of the stimuli was also altered by changing from black lines on a white background (Experiments 1 to 3) to white lines on a black background (all subsequent experiments). Pigeons attend to bright stimuli and seldom peck at dark ones. Therefore this reversal of the black and white features of the key should make it more likely that the pigeons were forced to attend to the line per se, and not just to the key as a whole. There is support for this from Freeman and Thomas (1967) and Newman and Benefield (1968), who showed that subjects produced steeper gradients when tested with different orientations of a line on a black background, provided the key was the only source of illumination.

Procedural changes need to be considered also, in efforts to establish dimensional stimulus control using an interdimensional training procedure. Hearst and Koresko (1968) gave varying amounts of training with a vertical line and obtained steeper gradients after more extended training. However, by "extended" training, they meant only 14 days, suggesting no extension of the length of training used in Experiment 3 (25 sessions) would have affected the obtained gradients.

The purpose of Experiment 4 was to test the acquisition of dimensional stimulus control around both S1 and S2 rather than around S2 alone, as was attempted in Experiment 3. This would provide a clear evaluation of the effectiveness of the procedural and stimulus changes in developing dimensional control. To heighten the comparability of these results with those obtained by others, the discrimination training procedure involved MULT VI EXT only with no SIG group.

Although single-stimulus training was used as the baseline phase in Experiment 3, a MULT VI-60sec VI-60sec schedule was again adopted as the baseline in Experiment 4, to make the procedure more directly comparable with that of the first two experiments and to establish that it was indeed the EXT procedure which accounted for any difference in response rates between S1 and S2 during discrimination training. Most interdimensional studies have used initial single-stimulus training (e.g. Farthing and Hearst, 1972; Hearst, Besley and Farthing, 1970; Selekman, 1973).

CHAPTER VI

EXPERIMENT 4

1. AIM

Several reasons have been suggested for the failure to obtain dimensional stimulus control using a variety of generalization tests in Experiment 3. One possibility is that some of the stimuli associated with each reinforcement schedule (i.e. VI-60sec, EXT, or VI-60sec[SIG]) were not those varied during generalization testing, and that these other stimuli overshadowed the effects of the ones assumed to be most relevant. An attempt was made to reduce the influence of such stimuli in this experiment by using different training and test stimuli (see details in Method section below). In Experiment 3, dimensional stimulus control around S2 only was investigated. Nothing is known about the nature of the dimensional stimulus control around S1 for those same subjects. Therefore in Experiment 4, generalization testing was carried out on two dimensions for each subjects, viz. around S2 and also around S1.

2. METHOD

The specific characteristics of Experiment 4, over and above the method outlined in the General Method section, were as follows:

(i) Subjects

C1 to C8

(ii) Procedure

a. Preliminary training

During the preliminary phases the stimulus on the key was a blank white field. This stimulus was also later used as one of the training stimuli.

b. Baseline training

Unlike the baseline procedure for Experiment 3, involving single stimulus training, the baseline phase of Experiment 4 was a MULT VI-60sec VI-60sec schedule. The stimuli associated with each component were a blank "white" key (which actually appeared grey to the human eye) with a brightness of 70 lux, and a 45° line. In this and subsequent experiments, the line orientations were all stimuli comprising a white line on a black background. (In Experiments 1 and 2, the line stimuli were made up of black lines on white backgrounds.) This nondifferential training phase lasted for 23 sessions for subjects C1, C2, C4, C5 and C7, and for 24 sessions for subjects C3, C6 and C8.

c. Pre-discrimination training generalization test

This generalization test in extinction tested response rates to the following eight stimuli:

1	0°	white line on a black background	
2	15°	" " " " " "	
3	30°	" " " " " "	
4	45°	" " " " " "	(training stimulus)
5	60°	" " " " " "	

.....

6 75^{o} white line on a black background

7 90^{o} " " " " " "

8 blank key (training stimulus)

d. Discrimination training

The change in procedure from baseline training was that now a MULT VI-60sec EXT schedule was in operation for all subjects. The stimuli associated with each component of the multiple schedule are shown in Table 6.1. The assignment of stimuli as S1 or S2 was made on the following bases:

(i) The blank key was S1 for half the subjects and S2 for the other half.

(ii) Subjects which had a slightly higher response rate during baseline training to the blank key were assigned this stimulus as S2 in subsequent discrimination training, to counteract any possible response preference. Discrimination training continued for 28 daily sessions for all subjects.

e. Post-discrimination training generalization tests

Each subject was given two generalization tests in extinction, so that gradients were obtained around both S1 and S2. The line orientation generalization test was conducted first, and followed the procedure of the pre-discrimination training generalization test. On the next day a generalization test was conducted along a brightness dimension. The brightness of the stimuli presented during this test is shown in Table 6.2. Apart from the test stimuli presented,

Table 6.1

Experiment 4:

Stimuli associated with each component of the MULT VI-60sec EXT schedule during discrimination training.

Subject	VI-60sec stimulus (S1)	EXT Stimulus (S2)
C1	blank key	45^{o} line
C2	45^{o} line	blank key
C3	blank key	45^{o} line
C4	45^{o} line	blank key
C5	blank key	45^{o} line
C6	45^{o} line	blank key
C7	45^{o} line	blank key
C8	blank key	45^{o} line

Table 6.2

Experiment 4:

Stimuli presented during brightness dimension generalization testing.

Stimulus name	Brightness of key (in lux)
1	235
2	163
3	115
4	70 (training stimulus)
5	18
6	10
7	1
45° line	8 (training stimulus)

in all other respects the procedure for this test followed that of other generalization tests in extinction.

f. Discrimination training (Part II)

Following these generalization tests, each subject then had three more sessions of MULT VI-60sec EXT discrimination training.

g. Resistance-to-reinforcement tests

The final phase involved resistance-to-reinforcement generalization tests for all subjects around the "S2 dimension" only. Thus, subjects C1, C3, C5 and C8 were tested using stimuli along the line orientation dimension, and subjects C2, C4, C6 and C7 were tested along the brightness dimension. Testing was repeated on successive days so that all subjects were given four resistance-to-reinforcement generalization tests. The reinforcement schedule in operation during testing was, as before, VI-60sec.

3. RESULTS

(i) Baseline and discrimination training

Table 6.3 shows the discrimination indices of the final six sessions of baseline and discrimination training, and Figure 6.1 shows the normalised response rates in S1 and S2 for all subjects during the MULT VI-60sec EXT discrimination training phase. The S1 rates demonstrate the occurrence of positive behavioural contrast in all subjects, although the extent of this varied from subject

Table 6.3

Experiment 4:

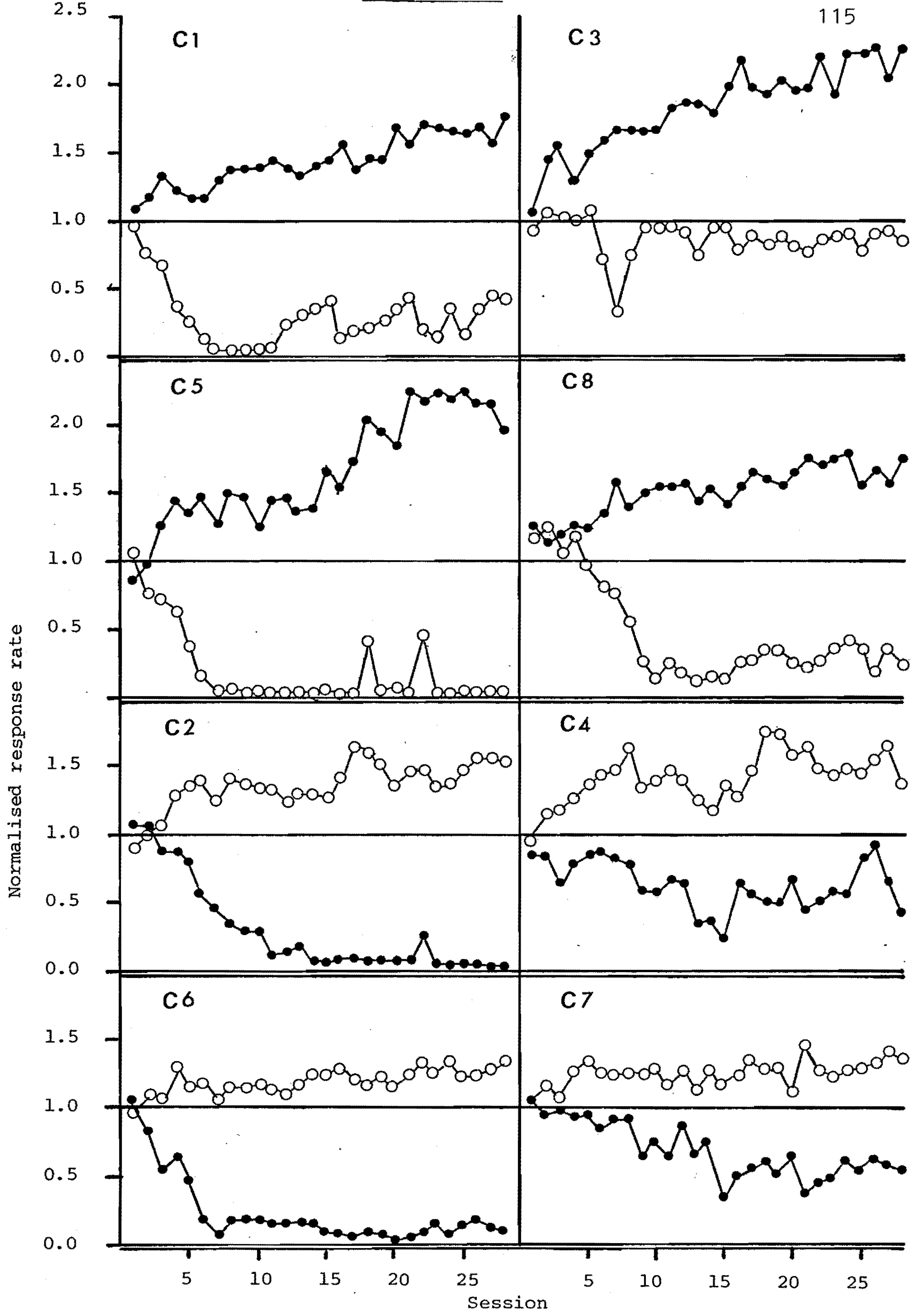
Discrimination indices for all subjects for the final six sessions of baseline and discrimination training.

Subject	MULT VI-60sec VI-60sec (baseline)	MULT VI-60sec EXT (discrimination)
C1	.47	.81
C2	.50	.98
C3	.48	.68
C4	.49	.68
C5	.48	.99
C6	.50	.90
C7	.50	.70
C8	.49	.83

Figure 6.1

Experiment 4: Normalised response rates for all subjects during MULT VI-60sec EXT. S1 was a blank white key for subjects C1, C3, C5 and C8, and a 45^{o} white line on a black background for subjects C2, C4, C6 and C7.

Figure 6.1



Responding in presence of blank white key

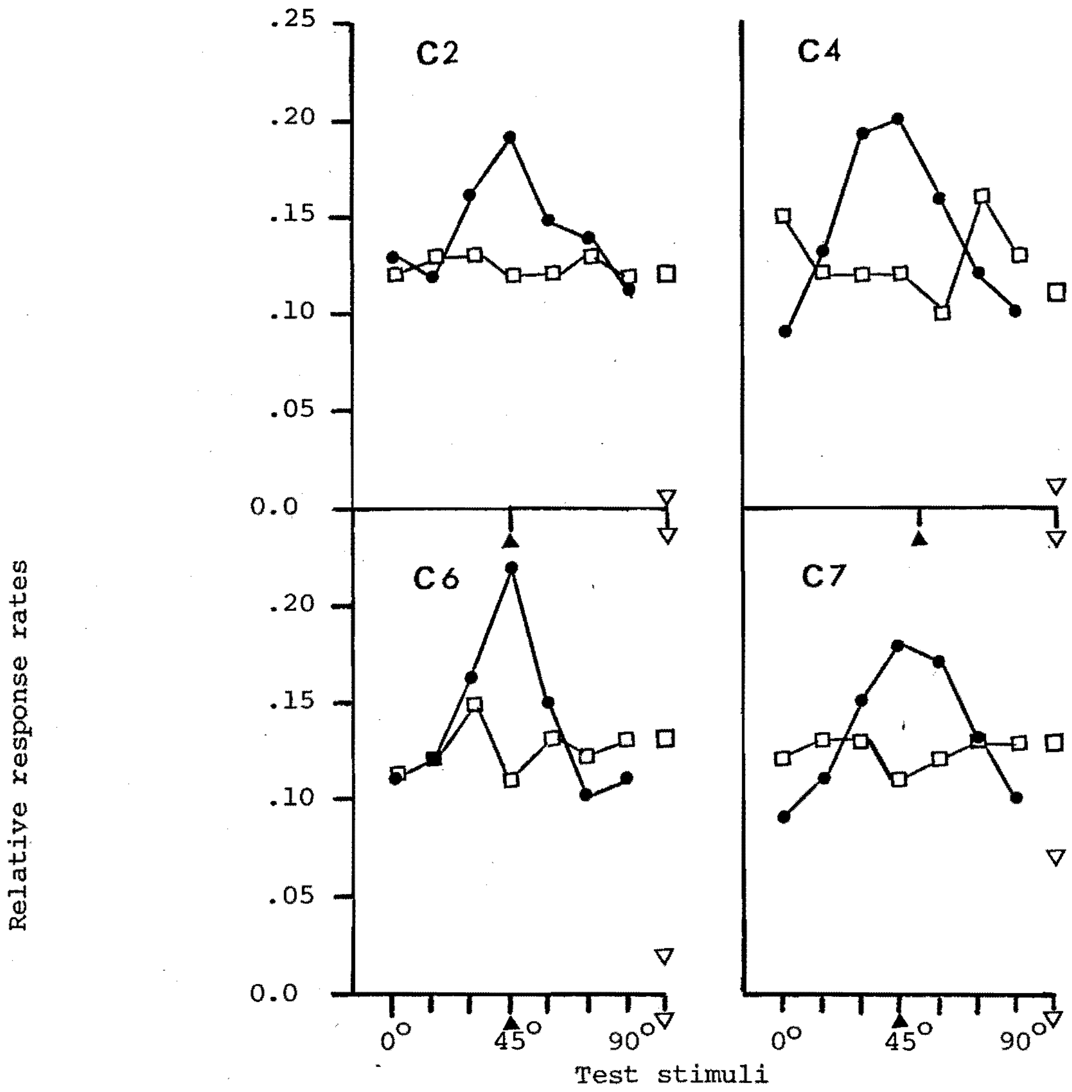
Responding in presence of 45^{o} white line on a black background.

to subject. All subjects showed response suppression in S2, although again the extent of this varied and is reflected partially in the discrimination indices at the termination of discrimination training.

(ii) Generalization tests in extinction

By testing along both the line orientation and the brightness dimensions, gradients were obtained around both S1 and S2 for all subjects. Figure 6.2 shows the generalization gradients obtained along the line orientation dimension for subjects C2, C4, C6 and C7. These are excitatory gradients around S1 (45° line), and all show maximal responding to S1 on the generalization test after discrimination training, but flat gradients on the pre-discrimination training generalization tests. These results are presented as relative response rates, and the extent of the dimensional stimulus control can be seen by assessing the variation in response rate to each stimulus from 0.125, which denotes equal responding to all stimuli. Figure 6.3 shows the generalization gradients obtained along the brightness dimension for these same subjects. None of these show symmetrical gradients with minima at S2 (stimulus no.4), but all show the trend of maximal responding to the darker stimuli (i.e. numbers six and seven) and much lower response rates in the presence of the stimuli at the brighter end of the continuum (i.e. stimuli numbers one to four).

Figure 6.2



Pre-discrimination training generalization test

Post-discrimination training generalization test

Responses to blank key during pre-test.

Responses to blank key during post-test.

S1 (45° white line on black background)

S2 (blank key)

Fig. 6.2 Experiment 4: generalization tests in extinction: relative response rates of subjects C2, C4, C6 and C7 along the line orientation dimension both before and after MULT VI-60sec EXT with a 45° white line on a black background as S1 and a blank key as S2

Figure 6.3

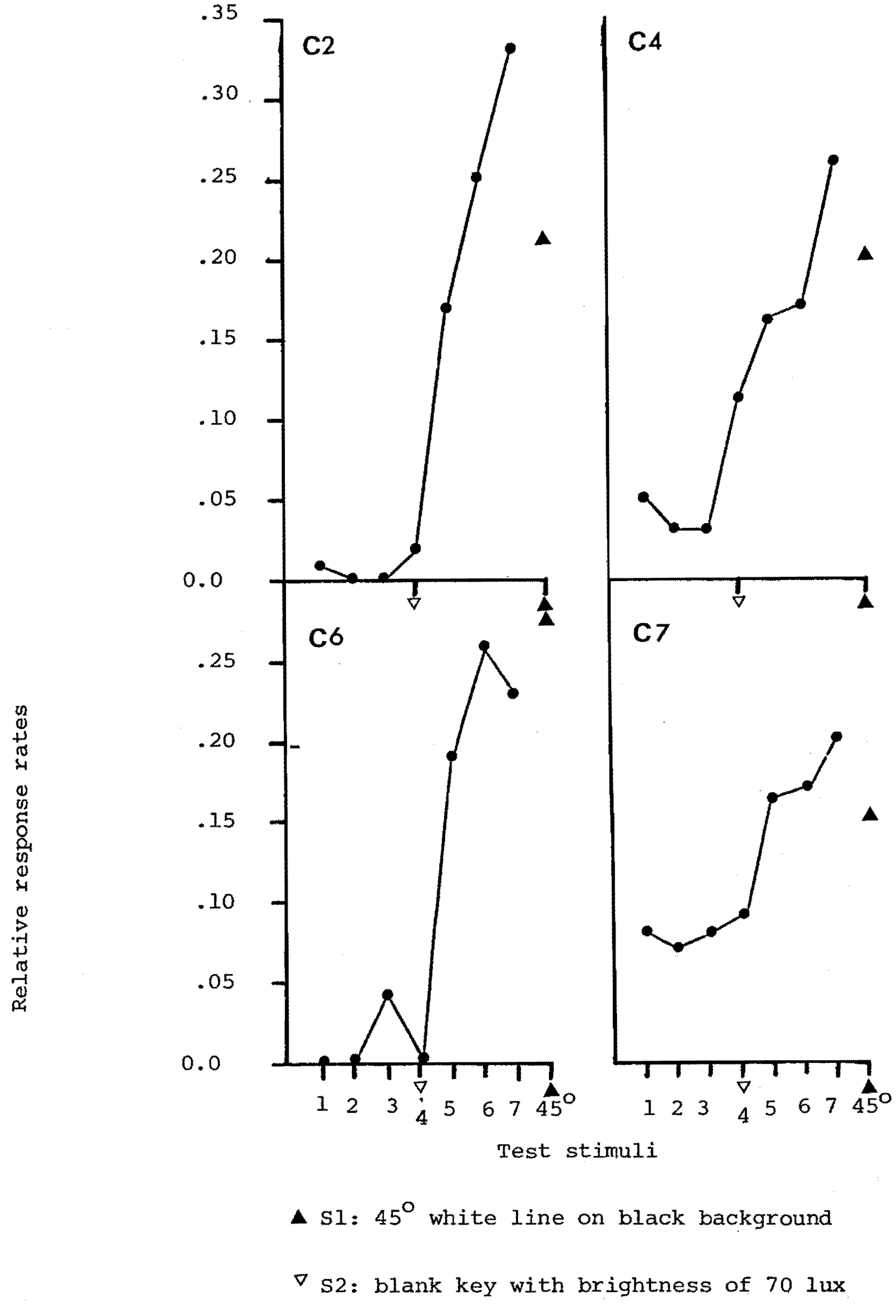


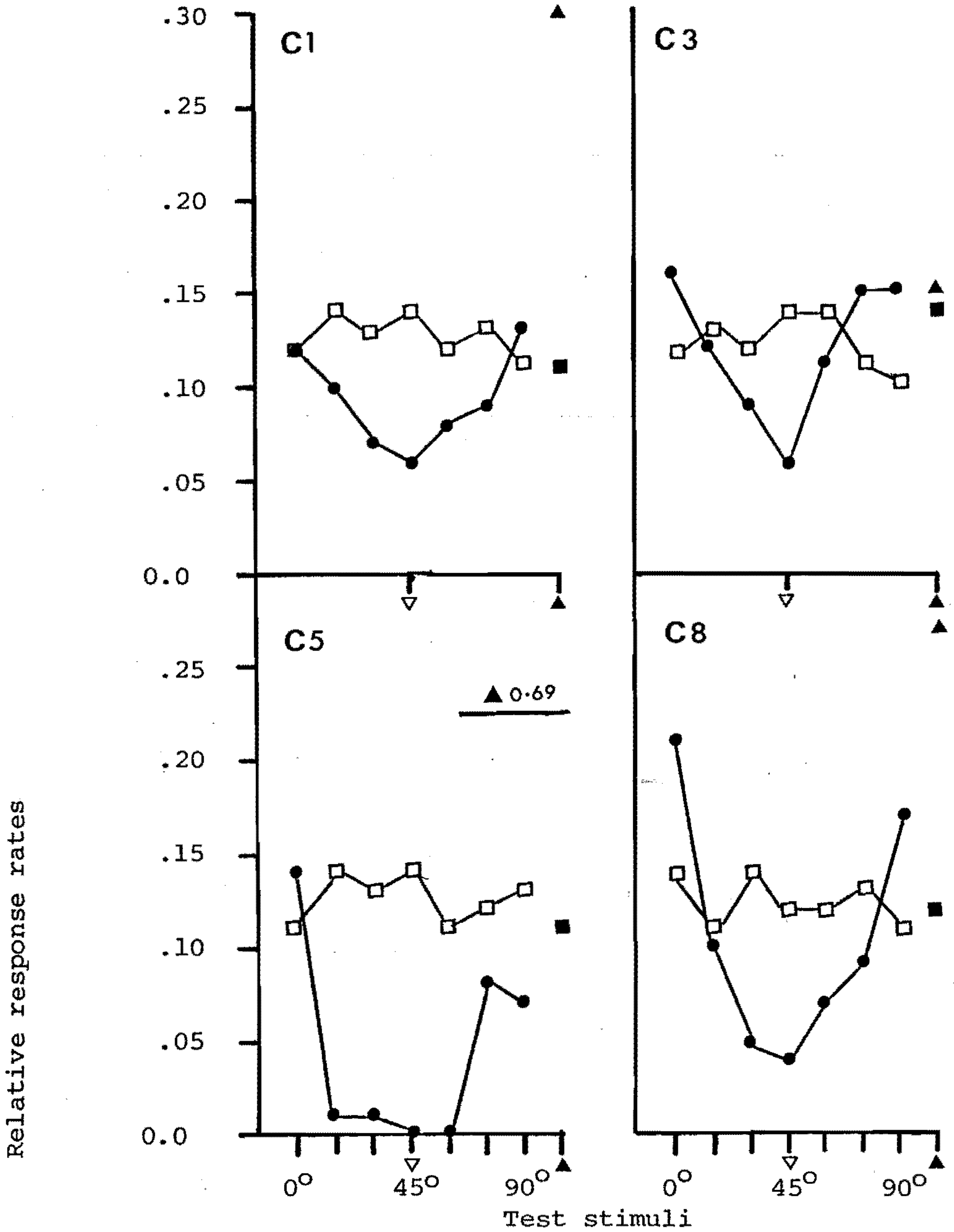
Fig. 6.3 Experiment 4: generalization tests in extinction: relative response rates of subjects C2, C4, C6 and C7 along the brightness dimension after MULT VI-60sec EXT with a 45° white line on a black background as S1 and a blank key of 70 lux as S2.

Comparable results are also obtained for the remaining subjects, C1, C3, C5 and C8, except that the stimulus control exerted by each of the test dimensions is the reverse of that for the other subjects. Figure 6.4 shows the generalization gradients obtained along the line orientation dimension for subjects C1, C3, C5 and C8 during both the pre- and post-discrimination training generalization tests. The results of the pre-training tests show no systematic dimensional stimulus control, but the relative response rates to each stimulus vary little around a value of 0.125 (indicating equal responding to all stimuli). In contrast, the gradients obtained during testing after discrimination training show clear evidence of dimensional stimulus control, with U-shaped gradients around the 45^{o} line, which had been S2 during MULT VI-60sec EXT training. Figure 6.5 shows the gradients obtained on testing these same subjects along the brightness dimension, i.e. around S1 (stimulus number 4). The gradients are not symmetrical but tend to maximal responding at or near stimulus no. 4, with a sharp decrement in response rate towards the darker end of the continuum.

(iii) Discrimination training (Part II)

The discrimination indices and normalised response rates of all subjects were calculated during this brief subsequent phase of discrimination training to assess the effects of the interposed generalization testing on MULT VI-60sec EXT response parameters for all subjects.

Figure 6.4



Post-discrimination training generalization test

Pre-discrimination training generalization test

S1: blank white key

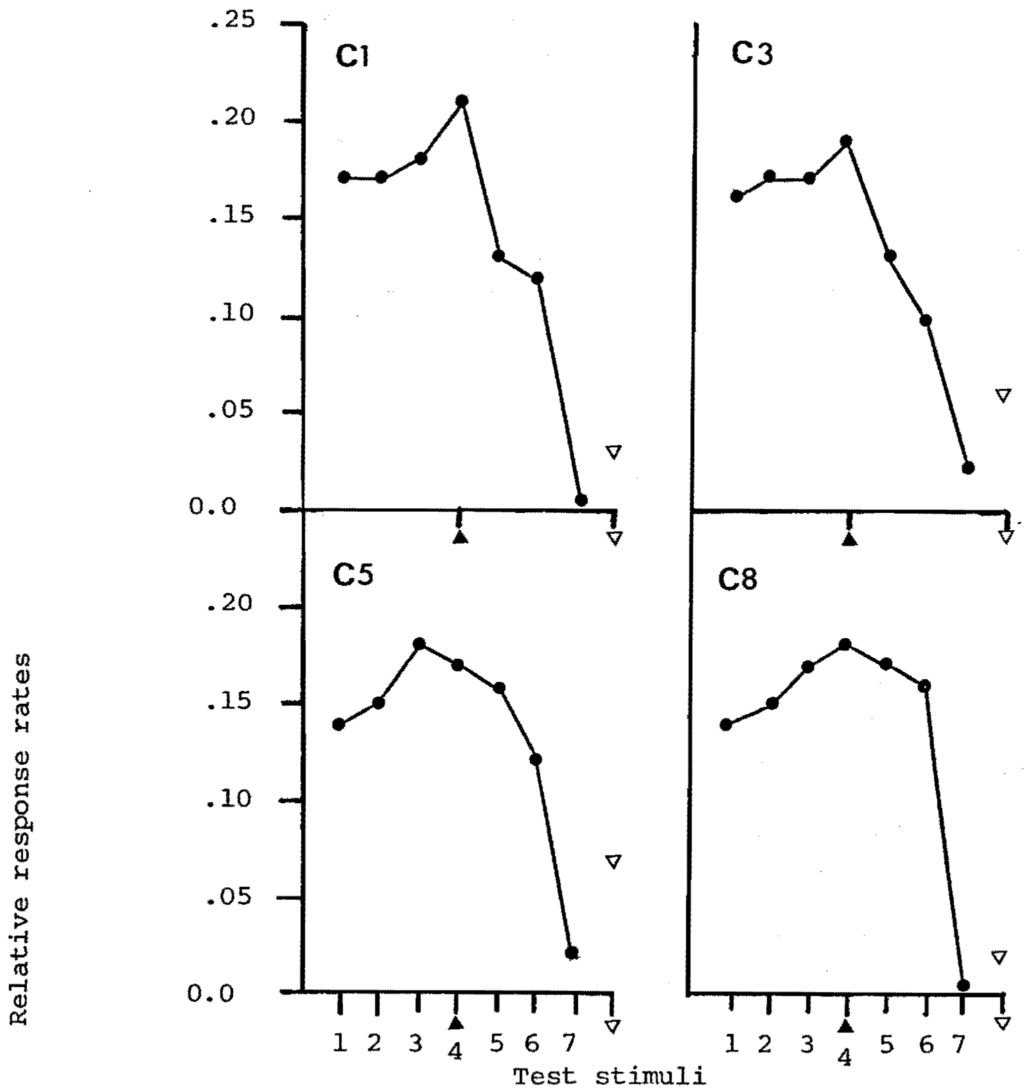
S2: 45° white line on black background

Responses to S1 during post-test

Responses to S1 during pre-test

Fig. 6.4 Experiment 4: generalization tests in extinction: relative response rates of subjects C1, C3, C5 and C8 along the line orientation dimension before and after MULT VI-60sec EXT, with a blank key as S1 and a 45° white line on a black background as S2.

Figure 6.5



▲ S1: blank key of 70 lux

▽ S2: 45^{o} white line on a black background

▽ Response rate to S2 during test

Fig. 6.5 Experiment 6.5: relative response rates of subjects C1, C3, C5 and C8 during the post-discrimination training generalization test in extinction along the brightness dimension following MULT VI-60sec EXT with a blank key of 70 lux as S1 and a 45^{o} white line on a black background as S2.

Responding was found to be very stable in terms of these parameters during the three sessions of discrimination training, so that it could be concluded that the generalization testing procedure did not alter discrimination training responding. Because of this, the resistance-to-reinforcement generalization tests were then conducted.

(iv) Resistance-to-reinforcement generalization tests

The data from the four sessions of resistance-to-reinforcement generalization tests are presented as relative response rates for each group of four subjects. Figure 6.6 shows the gradients obtained along the line orientation dimension for subjects C1, C3, C5 and C8. The first session produced a shallow U-shaped gradient with a minimum at the 45° line (S2, associated with EXT during training), but the gradients obtained subsequently did not continue this trend. The gradient of the fourth day appears to show the "flop-over" phenomenon (Hearst, Besley and Farthing, 1970) but this reversal of the gradient is merely an artifact of combining the individual data into one, as an inspection of the individual response rates would reveal (refer Appendix IV).

Figure 6.7 gives the relative response rates of the grouped data of subjects C2, C4, C6 and C7 on all four days of testing using resistance-to-reinforcement. The test dimension for these subjects was brightness, with stimulus no. 4 having been S2 during training. The gradient obtained during the first session is

Figure 6.6

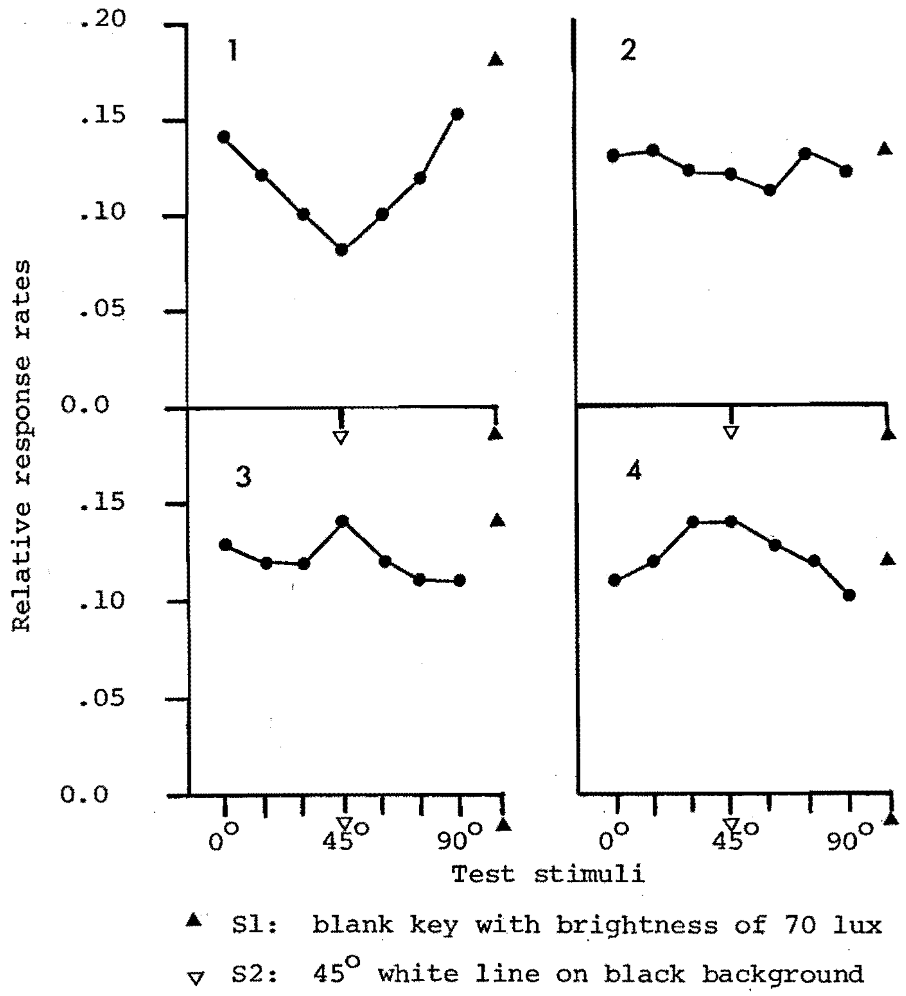


Fig 6.6 Experiment 4: grouped relative response rates of subjects C1, C2, C5 and C8 during four sessions of resistance-to-reinforcement generalization testing along the line orientation dimension. During prior MULT VI-60sec EXT training, S1 was a blank white key and S2 a 45° white line on a black background.

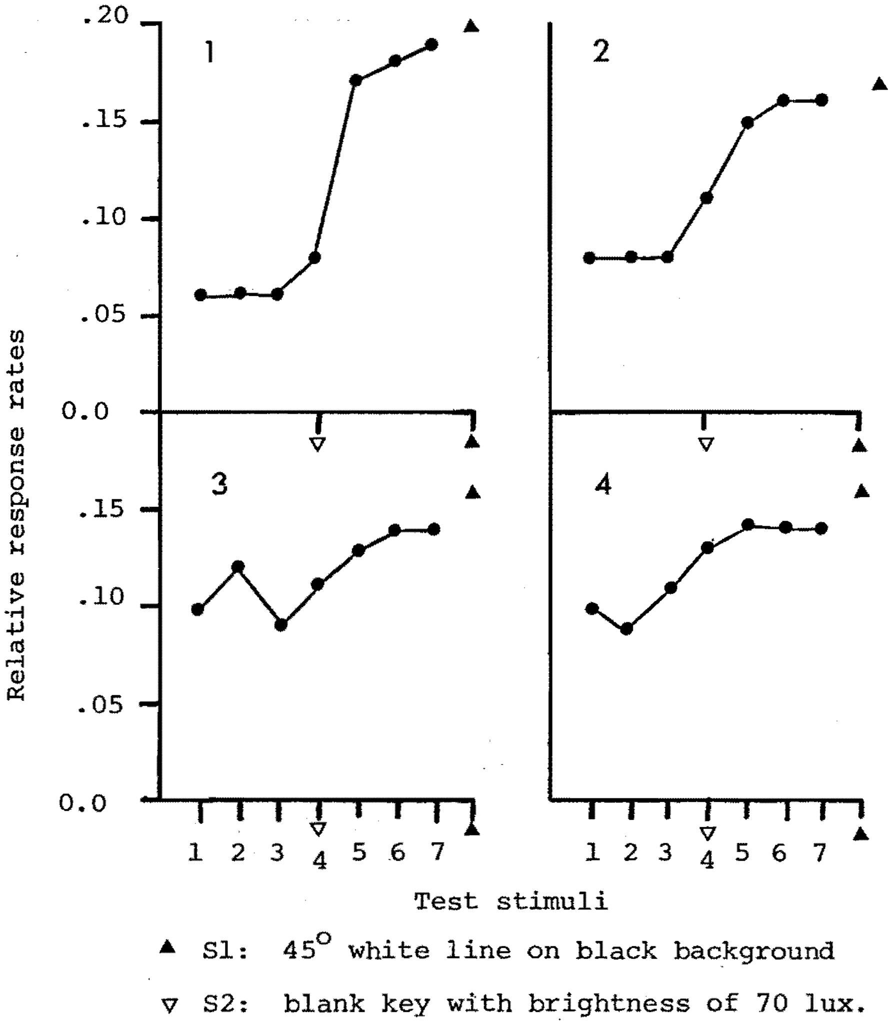


Fig. 6.7 Experiment 4: grouped relative response rates of subjects C2, C4, C6 and C7 during four sessions of resistance-to-reinforcement generalization testing along the brightness dimension. During prior MULT VI-60sec EXT training, S1 was a 45^{o} white line on a black background and S2 was a blank white key with a brightness of 70 lux.

comparable to those of Figure 6.3, obtained during generalization testing in extinction. The gradient is S-shaped, with least responding to the brightest stimuli (nos 1,2 and 3) and most to the darkest stimuli (nos 6 and 7). This trend is also apparent but less marked in the second session of resistance-to-reinforcement testing, but the gradients flatten out in the last two testing sessions.

4. DISCUSSION

(i) Generalization tests in extinction

Essentially, the line orientation tests for subjects C1, C3, C5 and C8 are the replication of Experiment 3 with the stimulus and procedural changes already discussed. Figure 6.4 gives clear evidence of U-shaped gradients around S2, indicating that the failure to produce dimensional stimulus control in Experiment 3 must have reflected methodological and measurement problems and not the absence of dimensional control per se. Experiment 4 extends the area of investigation of the previous experiment in measuring simultaneously-developed gradients around S1 as well as S2 for all subjects. Let us first consider the data of Figures 6.2 and 6.3, which give the generalization gradients obtained by the group C2, C4, C6 and C7. Unequivocal evidence of excitatory gradients around S1 is given in Figure 6.2, along the line orientation dimension. All show peaks at S1 although only the gradient obtained by C6 is truly symmetrical. In marked contrast, however, are the gradients shown in Figure 6.3, which are the gradients these same subjects produced along the brightness dimension around S2. All the gradients are grossly skewed, with few responses to the brighter stimuli and increasingly higher response rates with decreasing brightness of the test stimuli. Only one subject, C6, produced a gradient with a minimum at S2, and even in this case the two brightest stimuli also controlled zero response rates. Subjects C2, C4 and C7 all responded least to stimuli nos 2 or 3. And again, only C6 produced a higher response rate to S1 than to any of the brightness stimuli, a surprising result in gradients around S2, in which the highest response rate is usually still below that obtained in the presence of S1.

Thus, although the line orientation gradients produced by these subjects appear to be straightforward excitatory gradients around S1, the equivalent gradients around S2 along the brightness dimension are confounded by other factors. One possibility is that the darker stimuli intrinsically control higher rates of responding, an unusual situation in a species known to respond readily to bright stimuli. This is demonstrated in autoshaping procedures (Brown and Jenkins, 1968; Gamzu and Williams, 1971), and Kodera and Rilling (1976) cite evidence from several sources that "the rate of pecking a dark key is very low when responding on an illuminated key is reinforced". (p. 28)

The gradients shown in Figure 6.5 clearly show that the response rates along the brightness dimension do not reflect some intrinsic value of brightness as a controlling stimulus. This figure, giving the gradients around S1 for the subjects C1, C3, C5 and C8, also reveals asymmetrical gradients, but, unlike those of Figure 6.3, these gradients comprise high response rates to the brighter stimuli, and near-zero responding to the dark stimuli.

These results show that S1 and S2 are not strictly orthogonal. An important feature of interdimensional discrimination training is that one training stimulus is equidistant from all test stimuli along some dimension of the other training stimulus. It is true that the blank key is equidistant from all the line orientations, resulting in clear excitatory gradients around 45^{o} when that is S1 (i.e. for subjects C2, C4, C6 and C7) and inhibitory gradients around 45^{o} when that is S2 (i.e. for subjects C1, C3, C5 and C8), i.e. the blank key is orthogonal to the line orientations. The reverse does not apply: the 45^{o} line is not orthogonal to the brightness dimension. The brightness dimension responding is skewed in such a way that it suggests that the brightness of the 45^{o} line has affected the gradients. The overall brightness of the key when a line stimulus was presented was 8 lux, i.e. nearly equivalent to stimulus no.6 on the brightness dimension. Therefore, the asymmetry of the gradients of Figures 6.3 and 6.5 reflect a contaminant of the supposedly interdimensional training, demonstrating that along the brightness dimension, the line versus blank key discrimination was in fact intradimensional, and that the displaced maxima and minima reflect peak shift.

Because the two training stimuli are therefore orthogonal only with respect to the line orientation dimension, this procedure did not give clear, independent excitatory and inhibitory gradients obtained from each subject. However, the data presented in Figures 6.2 and 6.4 do give independent gradients around S2 and S1 respectively, but from different subjects. This provides a direct measure of the effects of identical training procedures and test stimuli upon dimensional control around both S1 and S2, a strategy first adopted by Honig, Boneau, Burstein and Pennypacker (1963). Prior to this, research on generalization gradients around S1 and S2 in pigeons was carried out along the wavelength dimension, and without directly equated training prior to the tests around each stimulus. Since then, much work has been carried out on dimensional stimulus control around S2 along a line orientation dimension (see Chapter V), but without equating these training conditions with those prior to testing around a dimension of S1. One experiment where this work has been extended, however, is that of Honig and Beale (1976), who paralleled the procedure of Honig, Boneau, Burstein and Pennypacker (1963) but using stimulus duration rather than response rate as the dependent variable. Like Honig et al (1963), Honig and Beale (1976) demonstrated the occurrence of decremental gradients around S1 and incremental gradients around S2, and discussed the theoretical implications of these in terms of excitation and inhibition.

(ii) Resistance-to-reinforcement tests

This procedure has been demonstrated by Rilling, Caplan, Howard and Brown (1975) to be a reliable measure of inhibitory stimulus control, as predicted and first described by Hearst, Besley and Farthing (1970). Similarly, Dawley and Denny (1974) demonstrated its effectiveness as a means of measuring excitatory gradients. In contrast with this literature on the resistance-to-reinforcement procedure, then, the results of Experiment 4 produce disappointingly little evidence of this procedure as offering any clarification of dimensional control already demonstrated using the traditional extinction paradigm during testing. In this sense, the results are not unlike those reported by Zentall, Collins and Hearst (1971).

The response bias evident along the brightness dimension during testing in extinction was also clearly apparent during the resistance-to-reinforcement tests, giving further support to the view that the two testing procedures are measuring some of the same aspects of stimulus control.

Experiment 4 therefore demonstrates that MULT VI-60sec EXT does result in the development of behavioural contrast during training, and later evidence of excitatory and inhibitory generalization gradients around S1 and S2. These results confirm the predictions inherent in the Spence-Hull model of gradient interaction, which predicts the occurrence of peak shift after comparable intradimensional training, attributing this to the algebraic summation of hypothetical separate excitatory and inhibitory gradients. The use of interdimensional training has produced such actual gradients, in support of the hypothesis. The other training procedure, viz. MULT VI-60sec VI-60sec(SIG), did not result in the development of peak shift and therefore does not fit the model of interacting gradients of excitation and inhibition. Therefore by now repeating the procedure using SIG in place of EXT as the S2 training condition, a further test of the Spence-Hull model can be made. If the SIG procedure did result in the development of U-shaped gradients around S2, this would indicate that the Spence-Hull model is insufficient to account for the differences between SIG and EXT in intradimensional training that were demonstrated in Experiments 1 and 2.

CHAPTER VII

EXPERIMENT 5

1. AIM

In Experiment 4 both inhibitory dimensional control around S2 and excitatory dimensional control around S1 were demonstrated following inter-dimensional discrimination training in which S2 was correlated with EXT. In Experiment 5, the S2 schedule was altered to SIG, and again generalization tests were conducted to evaluate the effects of this other response suppression procedure on the development of dimensional stimulus control. Because the shape of the gradients obtained along the brightness dimension in the previous experiment had appeared to reflect a confounding of responding along that dimension by control exerted by the brightness of the line stimulus, a different level of brightness was used as a training stimulus in Experiment 5. The stimulus used this time was equated for brightness with the 45° line stimulus, as closely as possible. However, the measure of the brightness of the line stimulus is only a gross measure reflecting an overall brightness of the key, and not of the actual line which on its own, would have a much higher value.

2. METHOD

The method adopted in this experiment paralleled that of Experiment 4, but with the following changes and specific characteristics:

(i) Subjects:

D1 D2 D3 D4 D5 D6 D7 D8

(ii) Procedure:

a. Preliminary training

The stimulus projected on to the key during the pre-training was a blank field with a brightness of 8 lux (later used as one of the training stimuli).

b. Baseline training

The procedure followed was similar to that of Experiment 4, i.e. a mult VI-60sec VI-60sec schedule where one stimulus was a 45° white line on a black background, and the other, the blank key. However, the blank key used in this Experiment was much darker than that used as a training stimulus in the previous one (8 versus 70 lux). Subjects D1, D2, D3, D4 and D7 had 20 days of baseline training, and the other three (D5, D6 and D8) required 21 days in order to satisfy the stability criterion.

c. Pre-discrimination training generalization test

Response rates in extinction were recorded in the presence of eight stimuli, viz:-

1. 0° white line on black background
2. 15° white line on black background
3. 30° white line on black background
4. 45° white line on black background (training stimulus)
5. 60° white line on black background
6. 75° white line on black background
7. 90° white line on black background
8. Blank key (8 lux) - (training stimulus)

d. Discrimination training

For all eight subjects this phase comprised training on a *mult* VI-60sec VI-60sec(SIG) schedule. For half the subjects, the blank key was S1, and for the other half, it was assigned as S2. Once again, its assignment as S1 or S2 was made on the basis of response rates to each stimulus during baseline training. The stimuli associated with each component for each subject are shown in Table 7.1. Each subject received 20 daily sessions of this training.

e. Post-discrimination training generalization tests

On two successive days, generalization tests in extinction were conducted along the dimensions of line orientation (as in the pre-discrimination training generalization test), and brightness. The stimuli presented in the latter were the same as those shown in Table 6.2 for Experiment 4, but the use of different light bulbs in the projector slightly altered the brightness of each stimulus, and the range of the recalibrations is given in Table 7.2. The other change, as already mentioned, is in the stimulus used as a training stimulus. Stimulus number 4 (70 lux) used in Experiment 4 was replaced by stimulus number 6 (8 lux) as the training stimulus during Experiment 5.

f. Discrimination training (Part II)

Three more sessions of *mult* VI-60sec VI-60sec(SIG) were conducted following these tests.

TABLE 7.1

EXPERIMENT 5: Stimuli associated with each component of the *mult* VI-60sec VI-60sec(SIG) schedule during discrimination training.

Subject	S1 Stimulus (VI-60sec)	S2 Stimulus (VI-60sec(SIG))
D1	Blank key	45^{o} line
D2	45^{o}	Blank
D3	45^{o}	Blank
D4	45^{o}	Blank
D5	Blank	45^{o}
D6	45^{o}	Blank
D7	Blank	45^{o}
D8	Blank	45^{o}

TABLE 7.2

EXPERIMENT 5: Stimuli presented during generalization testing along the brightness dimension.

Stimulus	Brightness of key in lux
1	204 - 218
2	140 - 155
3	102 - 108
4	66 - 68
5	16
6	8 (training stimulus)
7	1
45° line	8 (training stimulus)

g. Resistance-to-reinforcement tests

Four days of generalization testing using the resistance-to-reinforcement procedure were conducted for all subjects along the line orientation dimension only. Therefore for subjects D1, D5, D7 and D8 these tests were conducted on the dimension around S2, but for D2, D3, D4 and D6, the test dimension was that around S1. The reinforcement schedule in effect during testing was VI-60sec. There was no signalled reinforcement during testing.

3. RESULTS

(i) Baseline and discrimination training:

The discrimination indices for the final six sessions of baseline and discrimination training are shown in Table 7.3, and demonstrate the development of differential responding as a result of the added signal in S2. The normalised response rates in S1 and S2 during mult VI-60sec VI-60sec(SIG) are shown in Figure 7.1. As in previous experiments, there is evidence of positive behavioural contrast in S1 although the magnitude and stability of this varies from subject to subject. The evidence for response suppression in S2 is less clear: D1 showed response suppression on the first session of signalled reinforcement, but in the next two sessions, the S2 response rate rose to baseline levels. Nevertheless, this rise was far outstripped by the concurrent increased response rate in S1.

TABLE 7.3

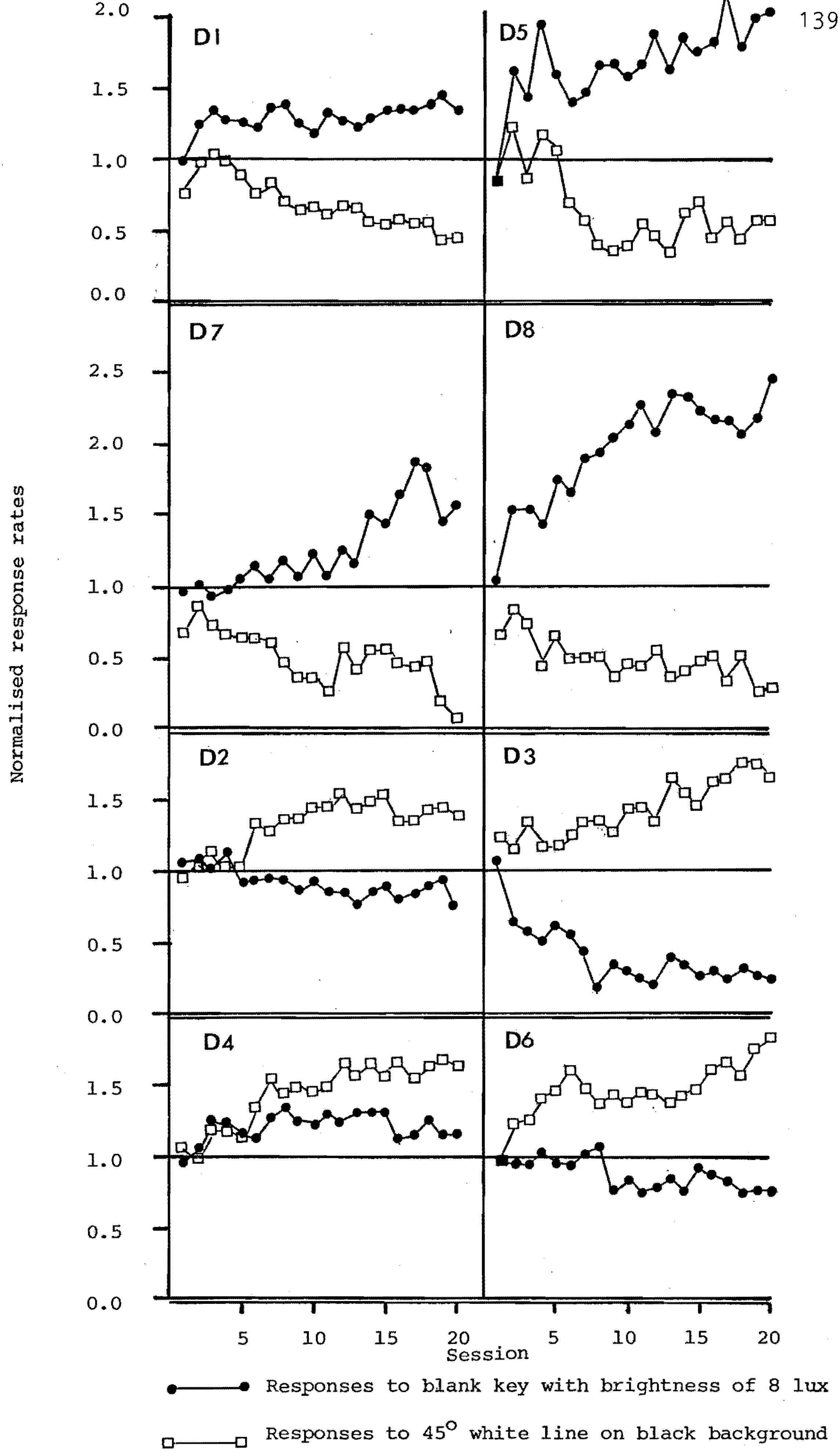
EXPERIMENT 5: Discrimination indices for the final six sessions of baseline and discrimination training.

Subject	*mult* VI-60sec VI-60sec (baseline)	*mult* VI-60sec VI-60sec(SIG) (discrimination)
D1	.48	.71
D2	.49	.62
D3	.48	.86
D4	.48	.56
D5	.48	.76
D6	.49	.65
D7	.50	.81
D8	.49	.85

Figure 7.1

Experiment 5: Normalised response rates to S1 and S2 during MULT VI-60sec VI-60sec(SIG).

Figure 7.1

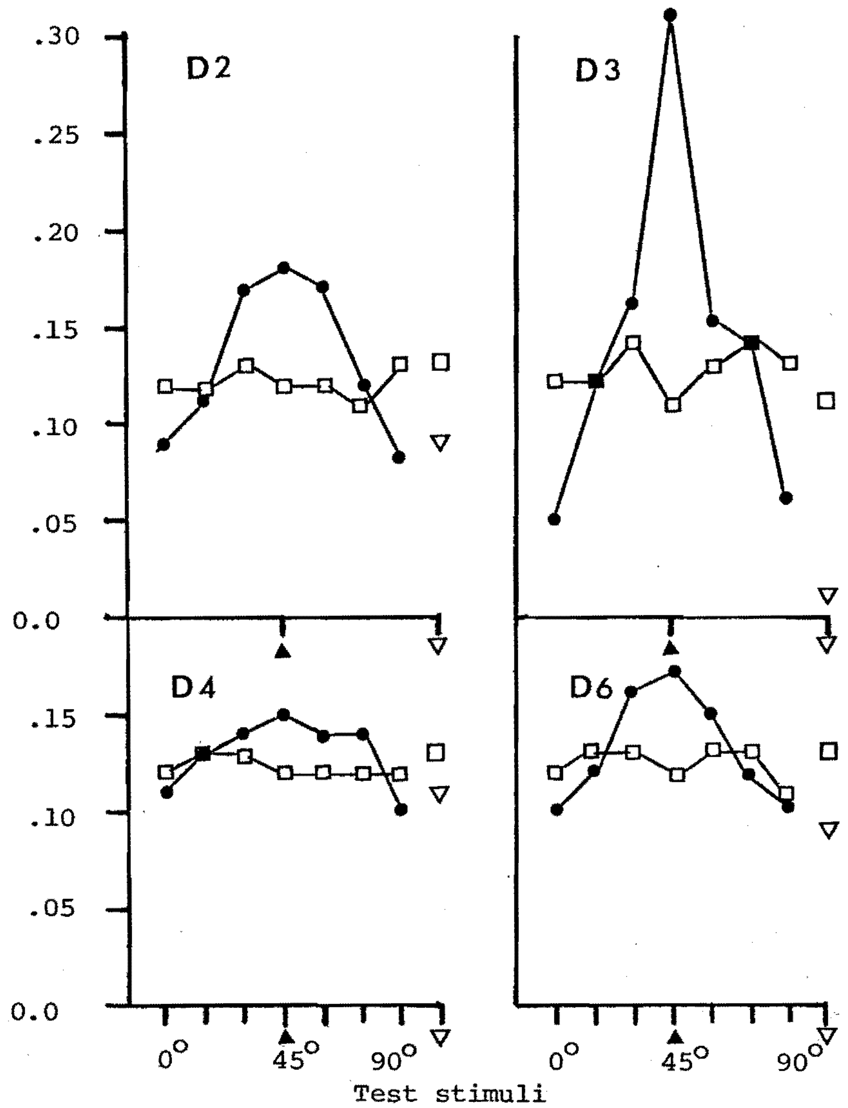

D1
D5
D7
D8
D2
D3
D4
D6
2.0
1.5
1.0
0.5
0.0
2.5
Normalised response rates
5
10
15
20
Session
Responses to blank key with brightness of 8 lux
Responses to 45° white line on black background

The S2 response rate again decreased but it was not until the eighth session that it fell below that of the first session. D5, D2 and D6 also showed little or no response suppression in S2 for five, four and eight sessions respectively, but thereafter their S2 response rates remained at lower levels than at the end of baseline training. D4, however, failed to show response suppression at all (despite the occurrence of a response rate increase in S1). The S2 response rate of this subject stabilised at a level higher than that of baseline training, i.e. positive induction rather than contrast occurred.

(ii) Generalization tests in extinction:

Figures 7.2 and 7.3 show the relative response rates along the line orientation dimension during both pre- and post-discrimination training generalization tests. There is no evidence of dimensional stimulus control during any of the pre-tests. The post-training test results shown in Figure 7.2 show clear excitatory gradients around S1 (45°) for D2, D3 and D6. This is less evident for D4, the subject which failed to exhibit response suppression in S2 during discrimination training, but did still show differential responding in S1 and S2. However, the complementary gradients shown in Figure 7.3, do not follow the same pattern. In this case, testing along the line orientation dimension, around S2, did not produce systematic gradients.

Figure 7.2



Pre-discrimination training test

Post-discrimination training test

▲ S1: 45° white line on black background

▽ S2: blank white key with brightness of 8 lux

□ Responses to S2 during pre-test

▽ Responses to S2 during post-test

Fig. 7.2 Experiment 5: Relative response rates of subjects D2, D3, D4 and D6 along the line orientation dimension around S1 during both pre- and post-discrimination training generalization tests in extinction.

Figure 7.3

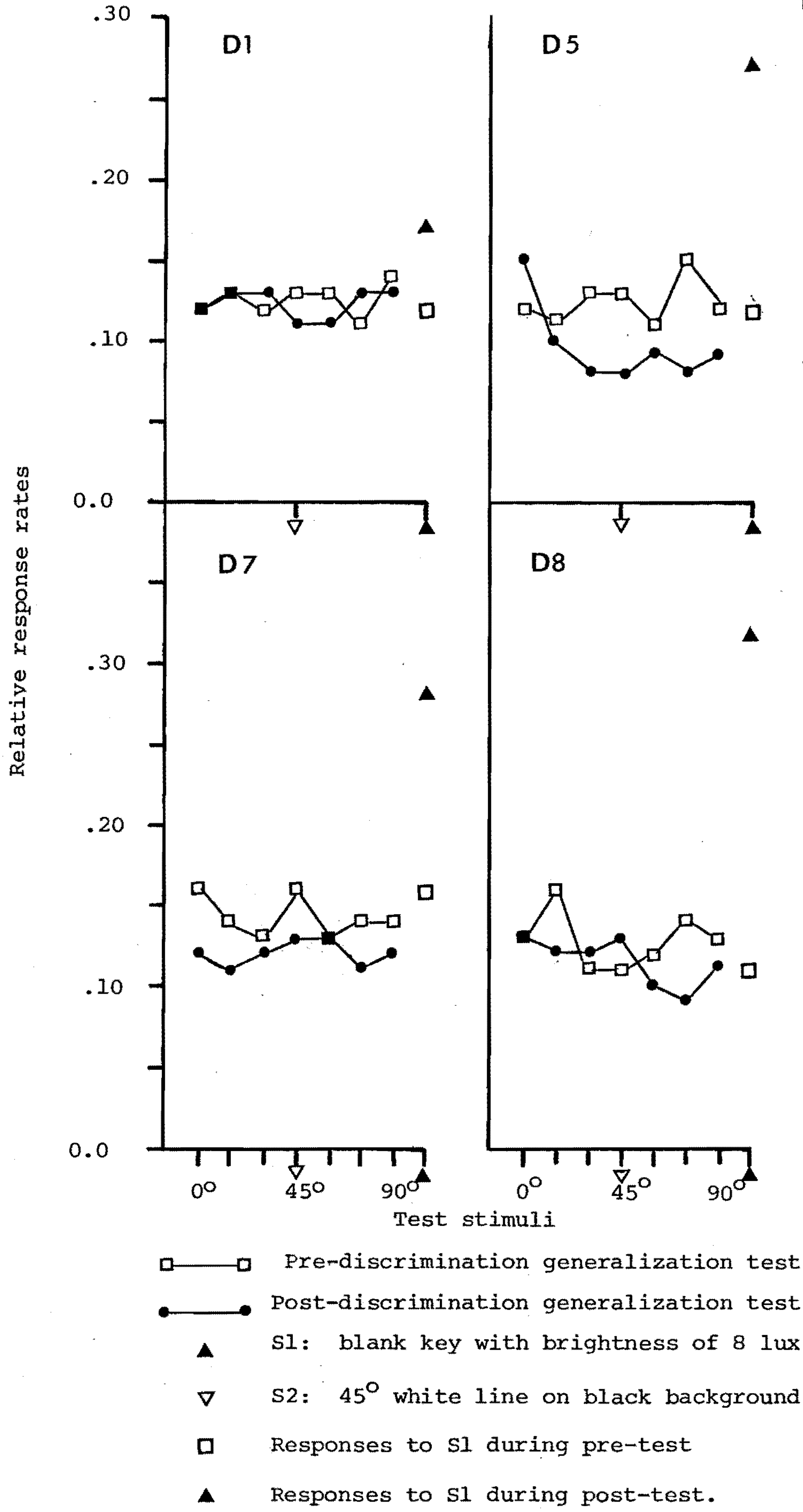


Fig. 7.3 Experiment 5: relative response rates of subjects D1, D5, D7 and D8 along the line orientation dimension around S2 during both pre- and post-discrimination training generalization tests in extinction.

Figures 7.4 and 7.5 show the gradients obtained from testing along the brightness dimension. Excitatory gradients around S1 (stimulus number 6) are apparent in all cases (i.e. subjects D1, D5, D7 and D8), although appear lop-sided because there was only one test stimulus darker than S1 (see Figure 7.4). Figure 7.5 gives the relative response rates of D2, D3, D4 and D6 around S2. Just as the gradients produced by the other group of subjects around S2, i.e. along the line orientation dimension, did not reveal systematic dimensional stimulus control, neither is this evident along the brightness dimension. While both D2 and D6 responded least to S2, the response rates to the other test stimuli do not constitute inhibitory gradients. Furthermore, the gradient produced by D4 under these same conditions appears to be excitatory.

(iii) Resistance-to-reinforcement generalization tests:

Figures 7.6 and 7.7 give grouped relative response rates during the generalization tests using the resistance-to-reinforcement procedure. All gradients are flat or nonsystematic, as would be graphed individual gradients.

4. DISCUSSION

(i) Discrimination training:

The results of this experiment support those of Experiments 1, 2 and 3 in demonstrating positive behavioural contrast on changing from *mult* VI-60sec VI-60sec to *mult* VI-60sec VI-60sec(SIG), just as

Figure 7.4

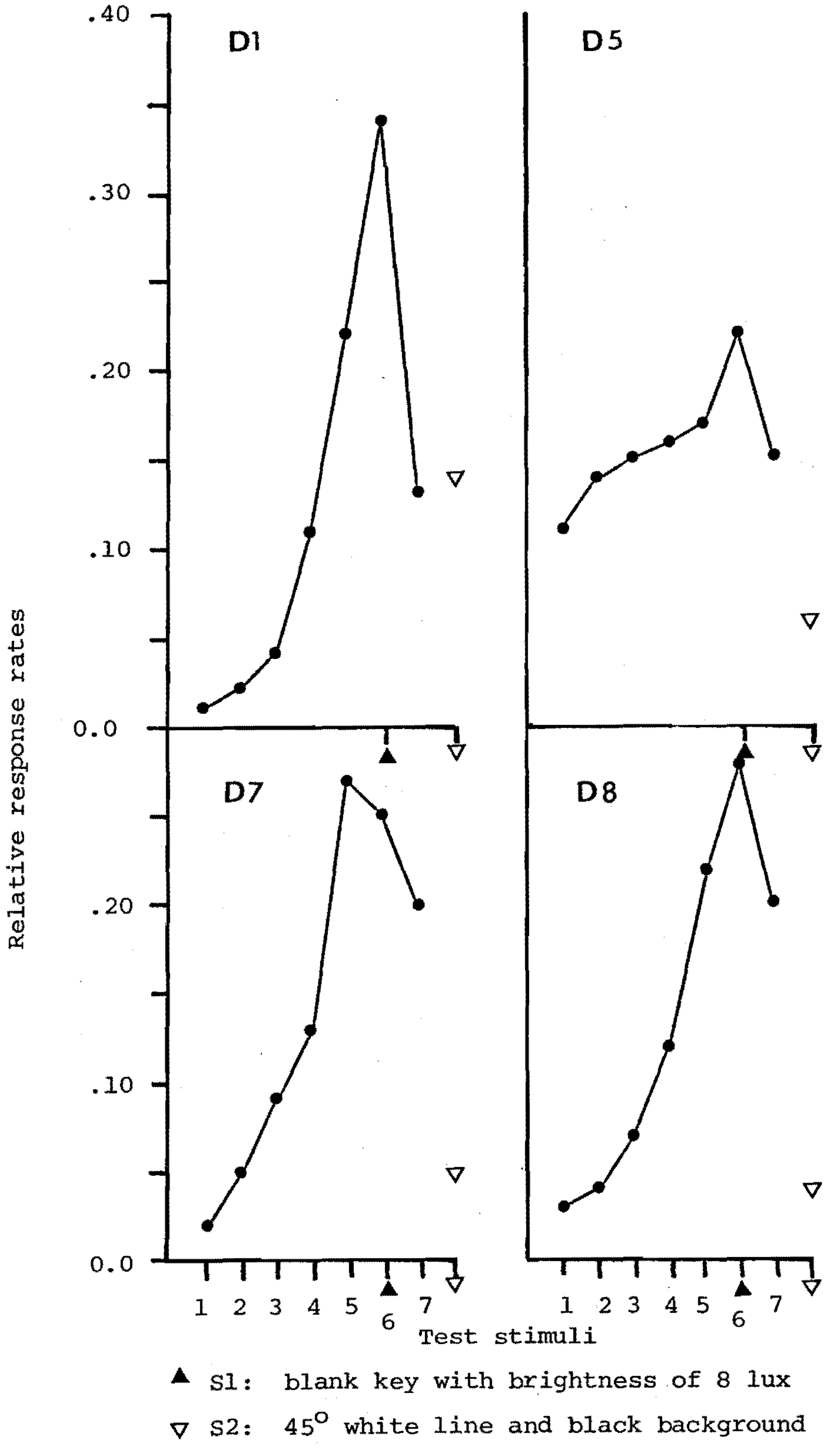


Fig. 7.4 Experiment 5: relative response rates of subjects D1, D5, D7 and D8 along the brightness dimension during post-discrimination training generalization test in extinction.

Figure 7.5

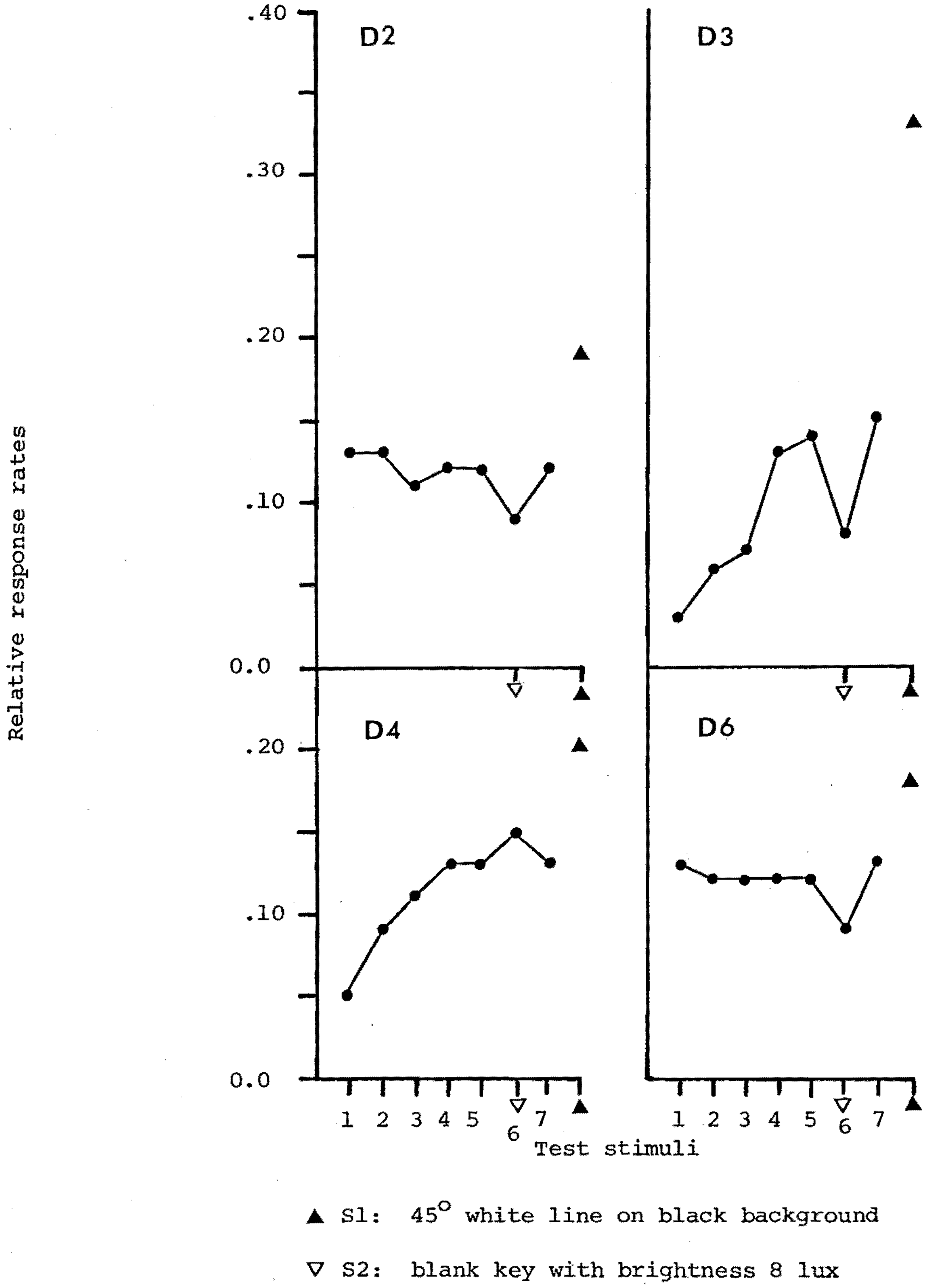


Fig. Experiment 5: relative response rate of subjects D2, D3, D4 and D6 along the brightness dimension around S2 during post-discrimination training generalization test in extinction.

Figure 7.6

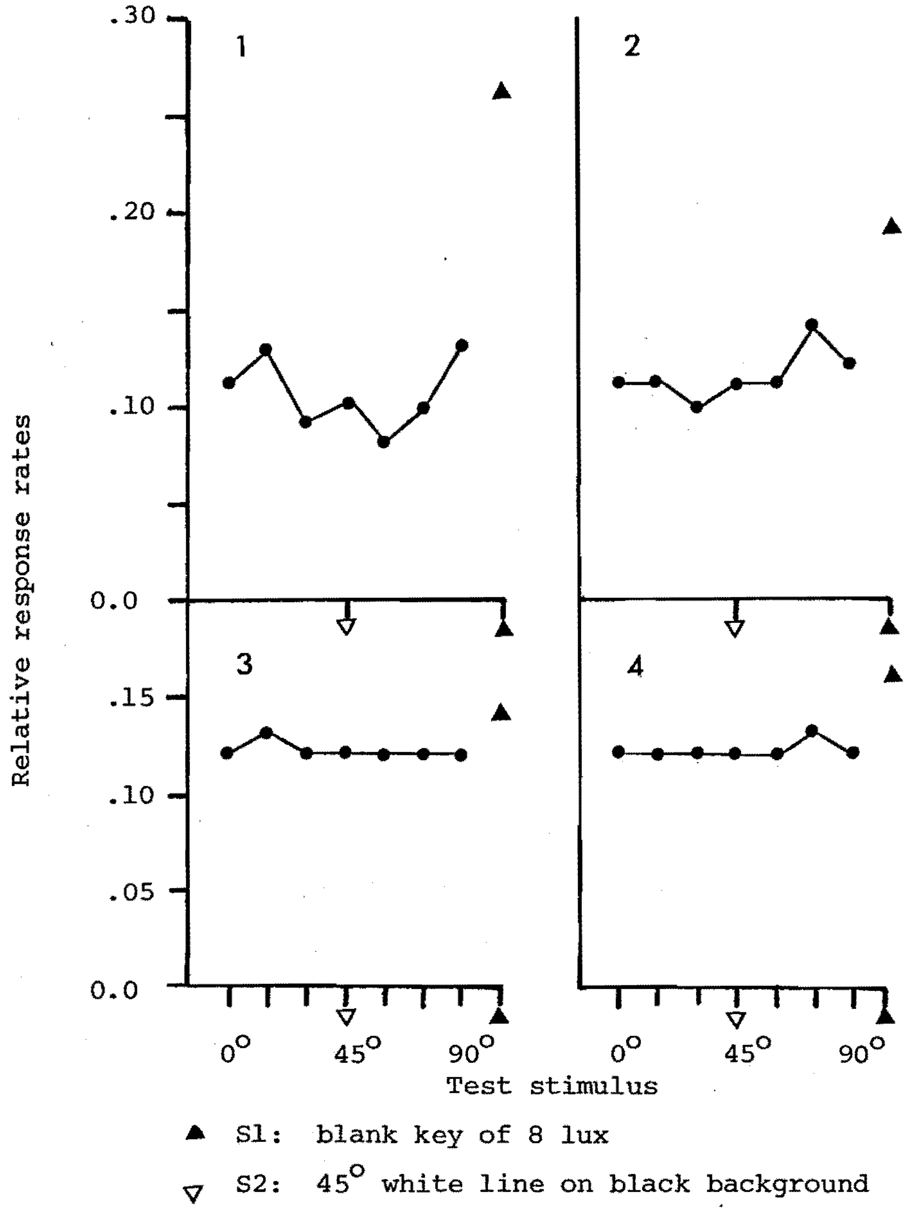


Fig. 7.6 Experiment 5: grouped relative response rates of subjects D1, D5, D7 and D8 along the line orientation dimension during three sessions of resistance-to-reinforcement generalization testing.

Figure 7.7

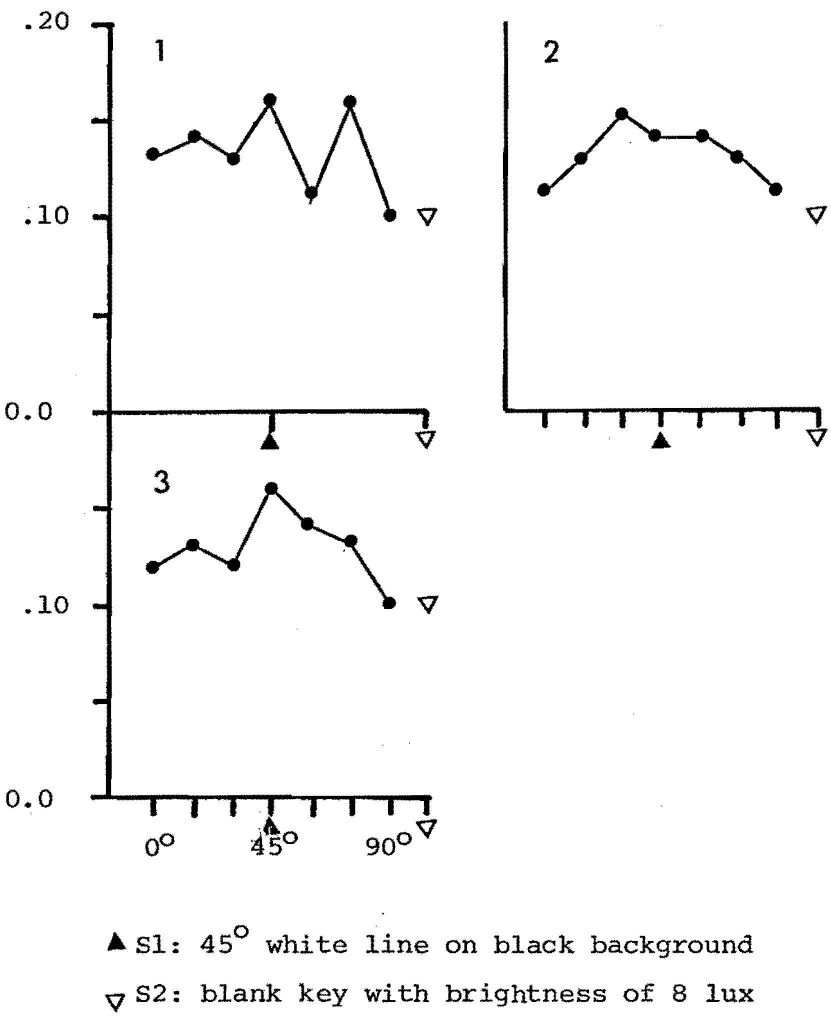


Fig. 7.7 Experiment 5: grouped relative response rates of subjects D2, D3, D4 and D6 along the line orientation dimension during three sessions of resistance-to-reinforcement generalization testing.

this occurs when the change is to mult VI-60sec EXT, as was also demonstrated in Experiment 4. The trend noted in these earlier experiments, of less response suppression in S2 during SIG training than during EXT, is again apparent when the discrimination training data of Experiment 5 are compared with those of Experiment 4. This does not imply less rigorous stimulus control by S2 if viewed in terms of optimal response rates. In extinction, the optimal response rate is zero, as no response is ever reinforced. Under signalled reinforcement conditions, however, some responses are reinforced, and at the same rate as previously in the presence of that stimulus, and also at the same rate as in the presence of the other stimulus operating in the multiple schedule (S1). Therefore while signalled reinforcement provides no change in the reinforcement frequency during S2, it still results in response suppression and other evidence of discrimination, particularly behavioural contrast.

Both the mult VI EXT and mult VI VI(SIG) paradigms are instances of operant discrimination learning. The reason the mult VI EXT paradigm is the most commonly used is simply because it does maximise both the extent of behavioural contrast and the discrimination index, as pointed out by Lander (1970) who states:

"... while the traditional paradigm (i.e. mult VI EXT) is an important one, we must remember that it is a special case."

(ii) Generalization tests in extinction:

Altering the brightness of one of the training stimuli from the 70 lux used previously, to 8 lux, appears to have resolved one of the problems associated with testing along the brightness dimension. The peaks of the gradients around S1 (Figure 7.4) are all at S1 itself, indicating independent excitatory gradients. However, the achievement of this result has been at the cost of other features of the procedure. With only one stimulus darker than the training stimulus during testing, these gradients are incomplete as demonstrations of dimensional stimulus control. It appears, for instance, that the slope of the excitatory gradients of Figure 7.4 would be steeper on the side of S1 where the stimuli are darker. It is impossible to tell from these results whether this reflects an intrinsically lower rate of responding to dark stimuli, or is an artifact of having too few measures in that range of brightness.

The blank training stimulus used in this experiment was kept at a brightness of 8 lux to equate it with the overall brightness of the key when the 45^{o} white line on a black background was projected on to it. It is arguable though that two stimuli such as these can never be equated for brightness, as when the line is projected on to the key, the whole stimulus, i.e. the key, is composed of two areas of clearly different brightness, i.e. the white line (very bright) and the black background (of very low brightness). It was not possible to measure the brightness of these two areas individually, but only to evaluate the brightness of the key as a whole. This latter measure, however, may have had no relevance to the pigeon subjects. The post-discrimination training gradients shown in Figure 7.2 show that the subjects were clearly able to discern and respond differentially to lines of differing orientations. A necessary precursor to this is the ability to attend to the distinction between the white (figure) and black (ground) elements of the stimulus presented on the key. This is quite a different matter from attending to the key as a whole. The microanalysis of the subjects' behaviour which would be required in order to elucidate this area is outside the range or intention of this experiment, and so the above analysis must remain only hypothetical.

In view of this, the vexed question of the adequacy of the brightness dimension in providing a series of independent gradients around S1 and S2 comparable with those along the line orientation dimension, must go unresolved. This further means that while the results shown in Figure 7.5 appear to support those of Figure 7.3 in failing to produce clear dimensional control around S2, this support is of limited value.

(iii) <u>Resistance-to-reinforcement tests</u>:

The failure of this procedure to demonstrate dimensional stimulus control is consistent with the results of generalization testing in extinction (see Figure 7.3), but cannot be taken as support for concluding that there is no such dimensional control following <u>mult</u> VI-60sec VI-60sec(SIG), because the results of Experiment 4 using the resistance-to-reinforcement procedure were similar. This procedure did not demonstrate dimensional control yet previous testing in extinction had produced U-shaped gradients around S2 after <u>mult</u> VI-60sec EXT.

The results of Experiment 4 (see Chapter VI) supported the suggestion that behavioural contrast is a necessary antecedent to the development of inhibitory dimensional stimulus control. This has had much other support, e.g. Terrace (1966a, 1968, 1971), Weisman (1969) and Yarczower (1970). The results of Experiment 5 clearly indicate that the prior occurrence of positive behavioural contrast does not necessarily predict the occurrence of inhibitory stimulus control. Neither does the occurrence of response suppression, which contradicts the conclusion drawn by Weisman (1969) that:

"... a reduction in the rate of responding to S2 (is) .. the determinant of discrimination learning resulting in inhibitory stimulus control."
(p.449)

The results of Experiment 5 best support the conclusion drawn by Couch (1975), that:

"Behavioral contrast is neither a necessary nor a sufficient condition for the development of inhibitory stimulus control."
(p.356)

The generalization gradients around S2 along the line orientation dimension in Experiments 4 and 5 confirm the predictions made from the gradients obtained in Experiments 1 and 2. The occurrence of peak shift following intradimensional training on a _mult_ VI-60sec EXT schedule was hypothesised as resulting from the algebraic summation of excitatory gradients around S1 and inhibitory gradients around S2. This hypothesis was supported in Experiment 4 by the occurrence of independent excitatory and inhibitory gradients following interdimensional training also on a _mult_ VI-60sec EXT schedule.

Conversely, there was no evidence of peak shift following intradimensional training on a _mult_ VI-60sec VI-60sec(SIG) schedule in Experiments 1 and 2. Folling interdimensional SIG training in Experiment 5, excitatory gradients did develop around S1 (Figure 7.2). But there was no evidence of either excitatory or inhibitory dimensional stimulus control around S2 (Figure 7.3). These results are also consistent with Spence's algebraic summation hypothesis.

CHAPTER VIII

EXPERIMENT 6

1. AIM

In Experiments 4 and 5, excitatory generalization gradients were obtained around S1 during testing in extinction after discrimination training. However, while the subjects in Experiment 4, trained with EXT as one component, produced clear evidence of inhibitory gradients around S2, the Experiment 5 subjects, trained with SIG in place of EXT, did not. Before conclusions can be drawn about differences in the nature of the dimensional stimulus control exerted by these two response suppression procedures, it must be ascertained that these differences do not reflect confounding due to the procedure used. One consideration is that all subjects in both these experiments had had considerable experience, during the baseline training phase, of S2 as an excitatory stimulus because responding was reinforced in this component on the same VI-60sec schedule as S1 responding. It is possible that this pre-training may have resulted in the development of excitatory dimensional stimulus control around S2 which was then overridden in Experiment 4 by later changing the S2 schedule from VI-60sec to EXT, but that the change, in Experiment 5, from VI-60sec to VI-60sec(SIG), unlike EXT, may not have altered the dimensional control around S2. Therefore, in this final experiment viz. Experiment 6, there was no baseline phase of *mult* VI-60sec VI-60sec. Instead, discrimination training was instituted straight after the initial few sessions of magazine training, etc.

A further change in this experiment was that, unlike the procedure in Experiments 3, 4 and 5, generalization testing was conducted along the line orientation dimension only, and not along the brightness dimension. This was because of the demonstrated lack of orthogonality between the line orientation used as a training stimulus, and the brightness dimension. Experiments 4 and 5 had established the development of excitatory gradients around S1 after both EXT and SIG training, but there were differences in the gradients around S2 obtained after these training procedures. Therefore, dimensional stimulus control around S2 only was tested in Experiment 6. And because there was no longer a need to attempt to equate the brightness of the training stimuli, the blank field used as S1 was again set at 70 lux.

The third major procedural change in this experiment was the addition of a generalization test along the line orientation dimension in the presence of the houselight, which had also served as the signal for reinforcer availability in the SIG group. The purpose of this test was to ascertain any differential control the signal may exert over generalization test responding in the SIG group, compared with this addition of a novel stimulus for the EXT group of subjects.

2. METHOD

The method adopted in this experiment was essentially similar to the interdimensional training procedure of Experiments 3, 4 and 5, but with the changes already discussed above and with the following specific characteristics:

(i) Subjects:

E1 E2 E3 E4 E5 E6 E7 E8

(ii) Procedure:

a. Preliminary training

The usual procedure was followed for the initial phases of magazine and key-peck training. During the latter, schedules were increased up to VI-60sec in the presence of a blank key with an illumination of 70 lux. This was to become S1 for all subjects in all later phases of the experiment. Unlike in previous experiments, there was no pre-discrimination training generalization test because there was no baseline training phase.

b. Discrimination training

Subjects E1, E2, E3 and E4 were trained on a mult VI-60sec EXT schedule with S1 as the blank key and S2, a 45^{o} white line on a black background. The other four subjects, viz. E5, E6, E7 and E8, were trained on mult VI-60sec VI-60sec(SIG) with the same stimuli serving as S1 and S2 as for the EXT group. This training was continued for a minimum of 20 consecutive daily sessions and then until the stability criterion was reached. Subjects had been randomly allocated to either the EXT or the SIG group.

c. Generalization tests in extinction

The eight test stimuli were the same as those used for line-orientation tests in Experiment 4 (Chapter VI). Two generalization tests in extinction were administered on consecutive days. The first of these followed the standard procedure of presenting the above stimuli in random order in EXT. In the second test, also in EXT, the stimulus conditions were altered. In this test, the houselight was on during the presentation of each of the eight stimuli. Previously the onset of the houselight had served as SIG, i.e. the signal for reinforcement availability for subjects E5 to E8, but to the EXT group subjects (E1 to E4), this houselight was a novel stimulus added to the test stimuli presented on the key.

d. Resistance-to- reinforcement generalization tests

For all subjects, generalization testing in the presence of the test stimuli only (i.e. the houselight was once again inoperative), was conducted on a VI-60sec schedule for six sessions on consecutive days.

3. RESULTS

(i) Discrimination training

The discrimination indices for the final six sessions of discrimination training are shown in Table 8.1, and demonstrate marked differential responding to S1 and S2 in all cases, although the indices of the SIG group are slightly lower than

TABLE 8.1

EXPERIMENT 6: Discrimination indices for the final six sessions of discrimination training.

Training Procedure	Subject	D.I.
mult VI-60sec EXT	E1	.92
	E2	1.00
	E3	.94
	E4	.93
mult VI-60sec VI-60sec(SIG)	E5	.93
	E6	.80
	E7	.70
	E8	.86

those of the EXT group. The reason for this difference between the two groups is shown in Figure 8.1, of the response rates in each component. Because there was no initial period of baseline training in either component, the data cannot be presented as normalised response rates but are presented as responses per minute, as they were for subjects B1 to B8 in Experiment 3 (see Figures 5.1, 5.5.1 and 5.5.2). On the whole, the EXT group (E1 to E4) exhibited greater response suppression in S2 and higher response rates in S1 than the SIG group (E5 to E8).

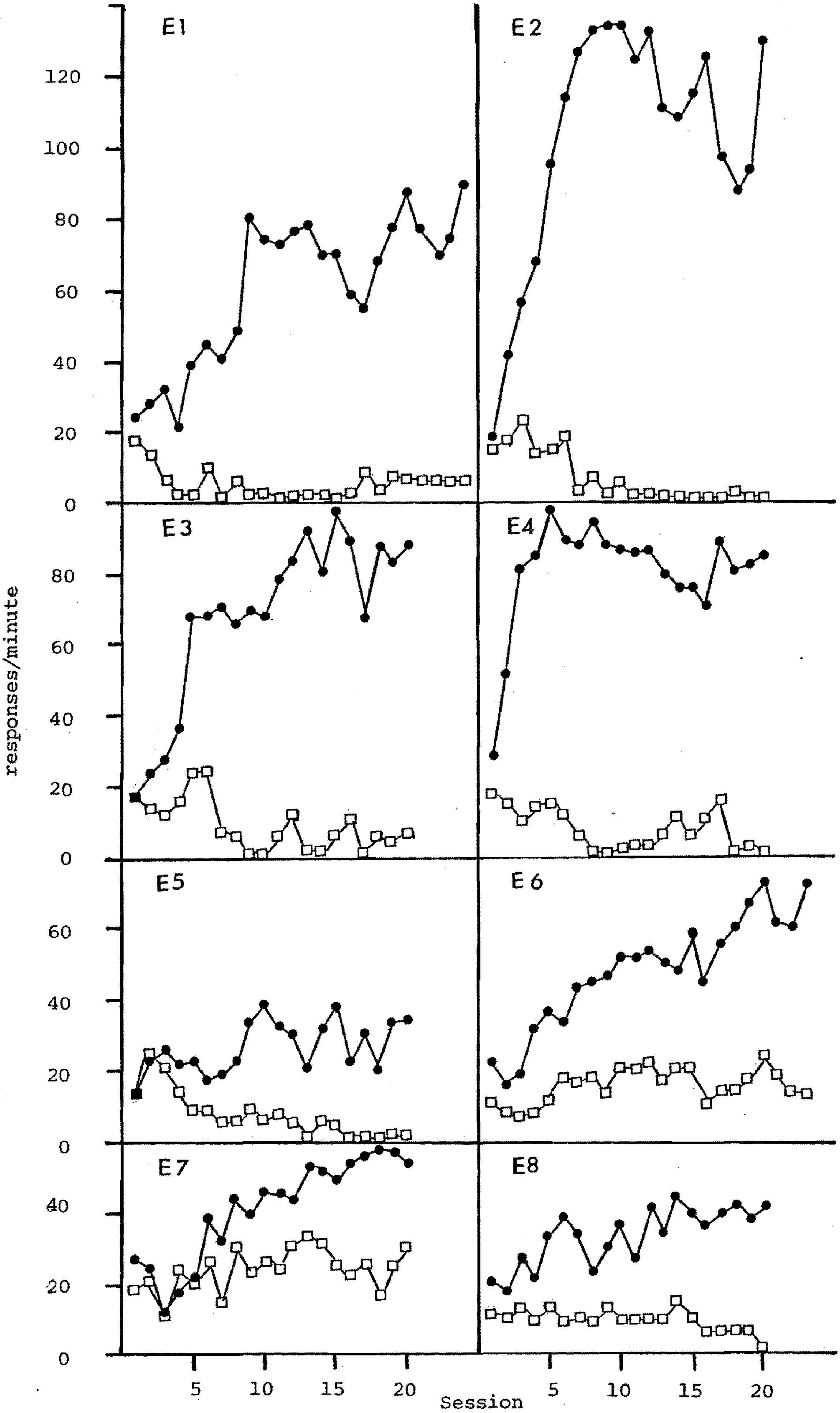
(ii) Generalization tests in extinction

Figures 8.2.1 and 8.2.2 show the relative response rates along the line orientation dimension during the first (post-discrimination training) generalization test in extinction. As the 45° line was S2 during training for all eight subjects, these figures show the extent of dimensional stimulus control exerted by S2. There are clear differences between the EXT (Figure 8.2.1) and SIG (Figure 8.2.2) groups. All four subjects trained on mult VI-60sec EXT (i.e. subjects E1 to E4) produced U-shaped gradients around S2, demonstrating the development of inhibitory dimensional stimulus control. This phenomenon is clearly established even though the shape of the gradients is not symmetrical (see Figure 8.2.1).

Figure 8.1

Experiment 6: Responses per minute of all subjects during discrimination training, which was *mult* VI-60sec EXT for subjects E1 to E4, and *mult* VI-60sec VI-60sec(SIG) for subjects E5 to E8.

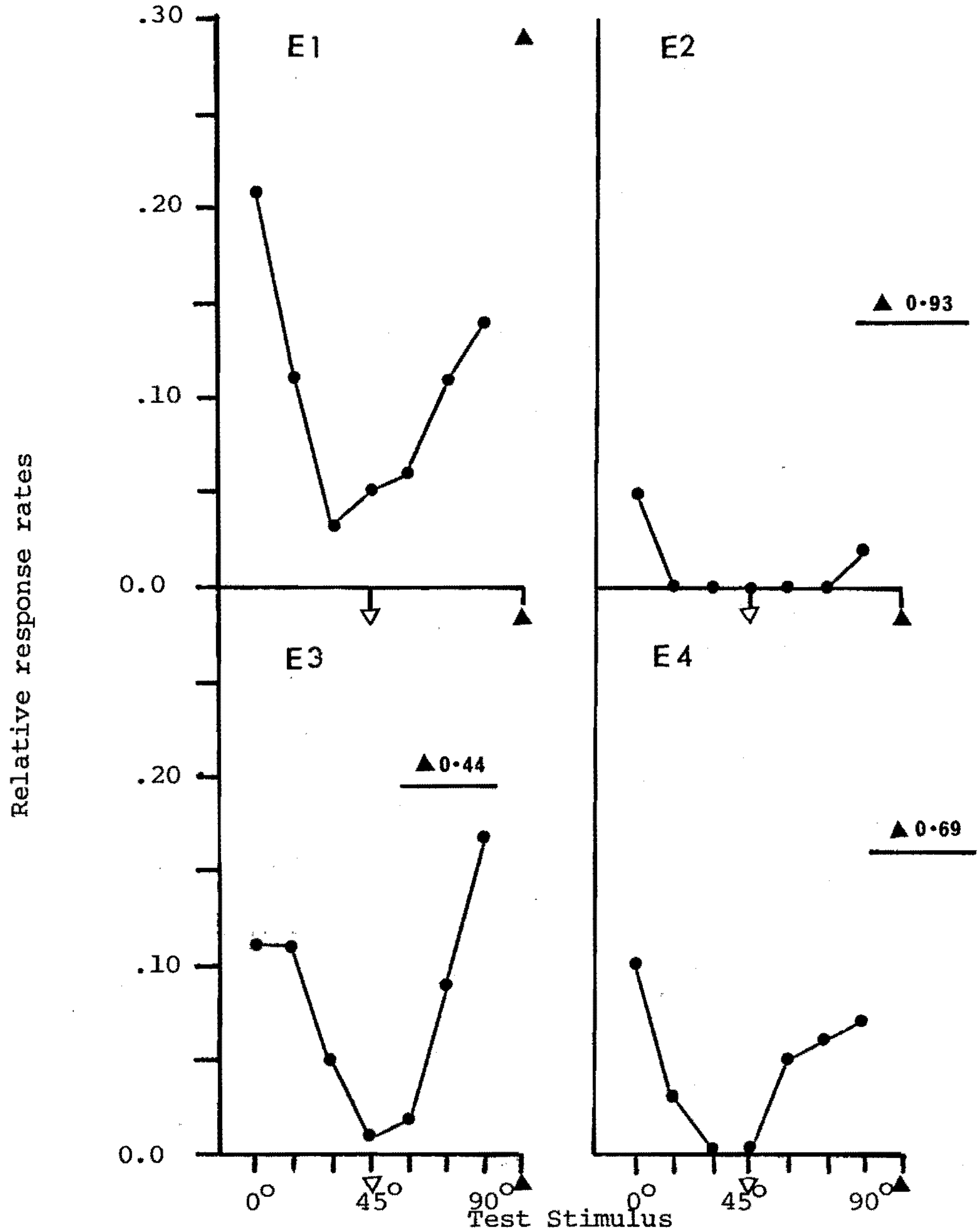
Figure 8.1



Responses to S1: blank key with brightness 70 lux

Responses to S2: 45° white line on black background

Figure 8.2.1

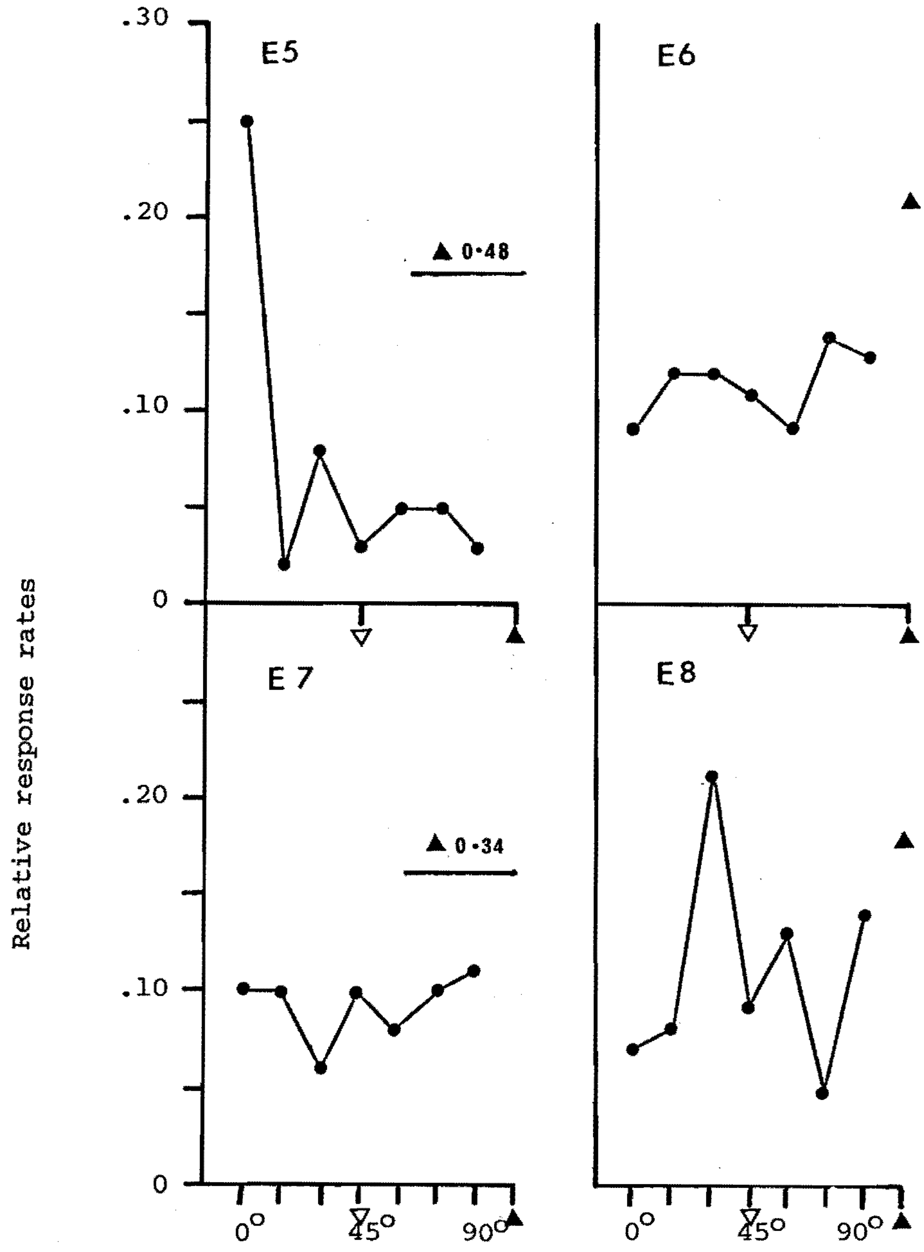


▲ S1: blank key with brightness of 70 lux

▽ S2: 45^{o} white line on black background

Fig. 8.2.1 Experiment 6: relative response rates of subjects E1, E2, E3 and E4 around S2 along the line orientation dimension after MULT VI-60sec EXT.

Figure 8.2.2

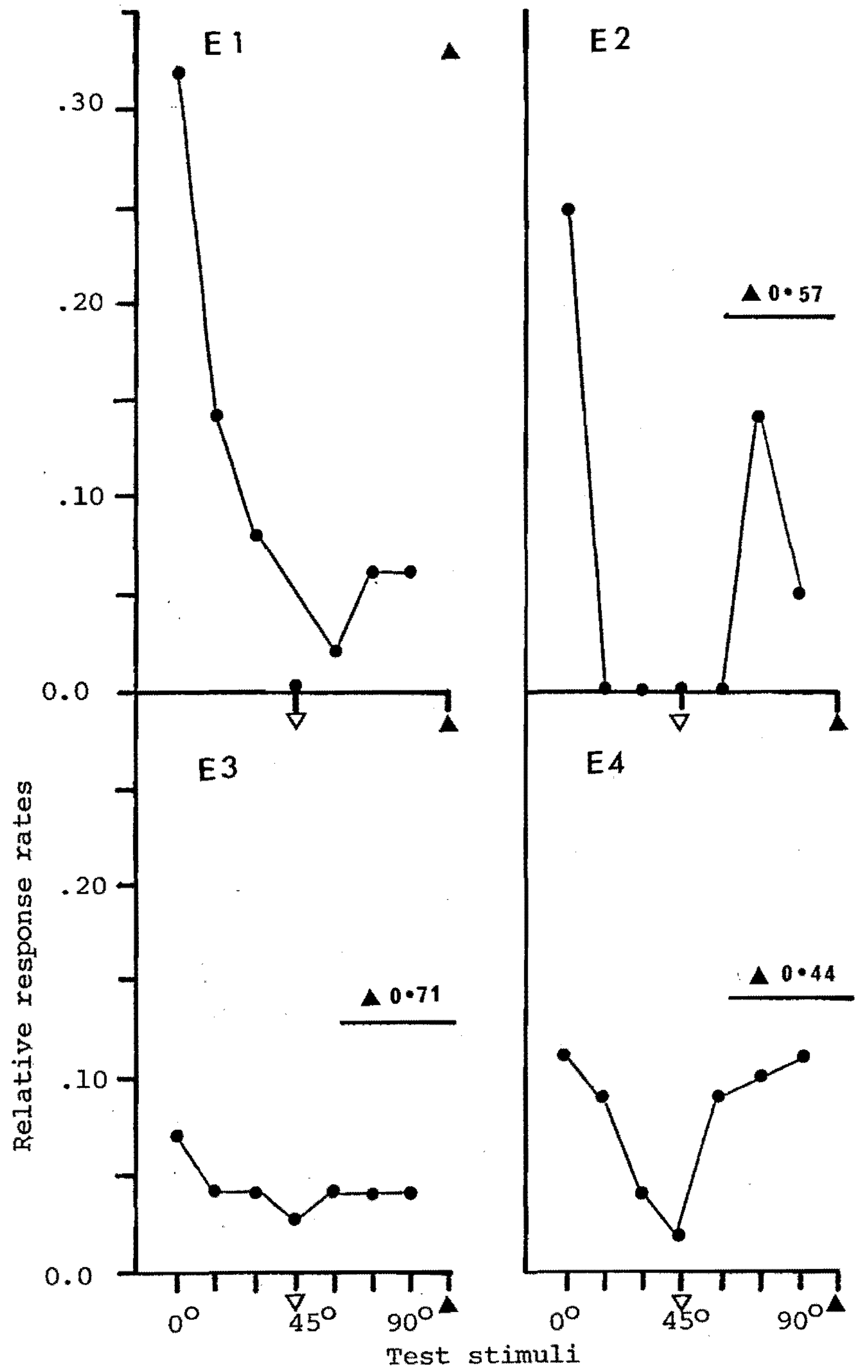


▲ S1: blank key with brightness of 70 lux

▽ S2: 45^{o} white line on black background

Fig. 8.2.2 Experiment 6: relative response rates of subjects E5, E6, E7 and E8 around S2 along the line orientation dimension after MULT VI-60sec VI-60sec(SIG).

Figure 8.3.1



▲ S1: blank key with brightness of 70 lux

▽ S2: 45° white line on black background

Fig. 8.3.1 Experiment 6: relative response rates of subjects E1 to E4 during generalization test in extinction along line orientation dimension in presence of houselight.

Figure 8.3.2

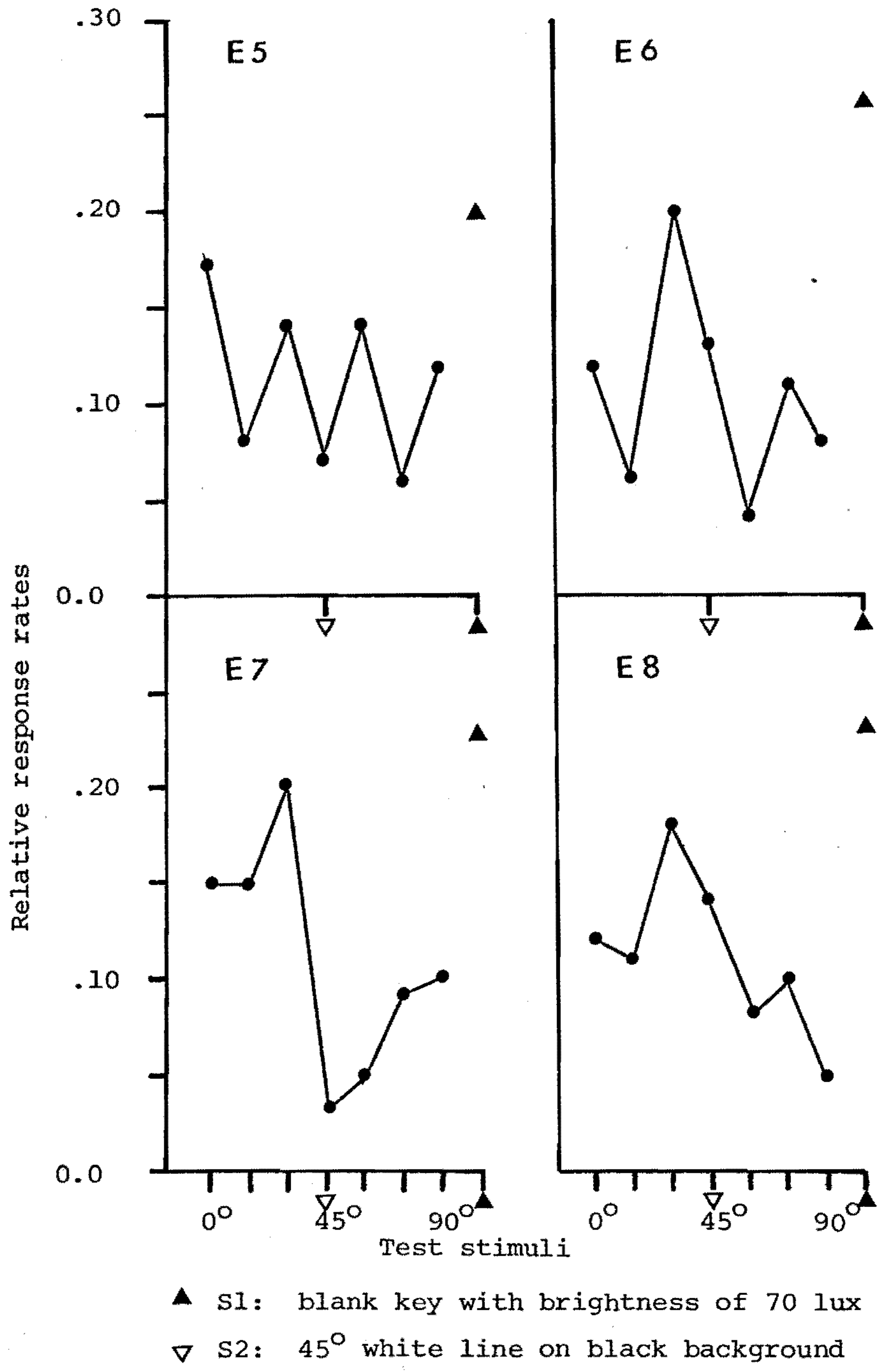


Fig. 8.3.2 Experiment 6: relative response rates of subjects E5 to E8 during generalization test in extinction along line orientation dimension in presence of houselight.

Only one subject, E3, responded least to S2 alone. E2 and E4 both produced minima at S2 but to adjacent stimuli as well. In E2 this reflects a "floor effect" resulting from very low rates of responding to all stimuli along the line orientation dimension, although high response rate was maintained to S1 during testing. E1 was the only one of the EXT group to respond minimally to a stimulus other than S2. Its lowest response rate was in the presence of an adjacent stimulus, viz. 30°. In all cases, far more responding occurred in the presence of S1 than to any of the line orientations.

In contrast, the gradients of Figure 8.2.2, produced by the SIG group, E5 to E8, certainly cannot be said to demonstrate inhibitory dimensional control. Apart from markedly higher response rates in the presence of S1, the gradients of this group do not reflect a consistent pattern. These results show that while both EXT and SIG suppress responding to S2 and to other stimuli along a dimension of S2, only the EXT procedure results in the development of inhibitory dimensional stimulus control.

Figures 8.3.1 and 8.3.2 give the relative response rates during the second generalization test in extinction, in which the houselight remained lit when the test stimuli were present on the key. On the whole, the addition of this extra stimulus made little difference to the shape of the gradients obtained in the EXT group (Figure 8.3.1). It did not substantially alter the response rates of E2, E3 and E4, but E1 responded at about half its rate during the first generalization test (see Appendix VI).

The cumulative records of the SIG group subjects differed from those of the first generalization test. In the earlier test, each subject tended to respond at a reasonably steady rate throughout each one-minute presentation of each stimulus, producing the familiar rough-grained record typical of VI schedule responding. But in this second test, where the stimuli were presented in the presence of the houselight, which had formerly been the signal indicating reinforcer availability, the cumulative records showed response rates within each one-minute presentation that were typical of extinction curves, i.e. negatively accelerating curves indicating a fall-off from an initially high rate of responding.

(iii) Resistance-to-reinforcement generalization tests

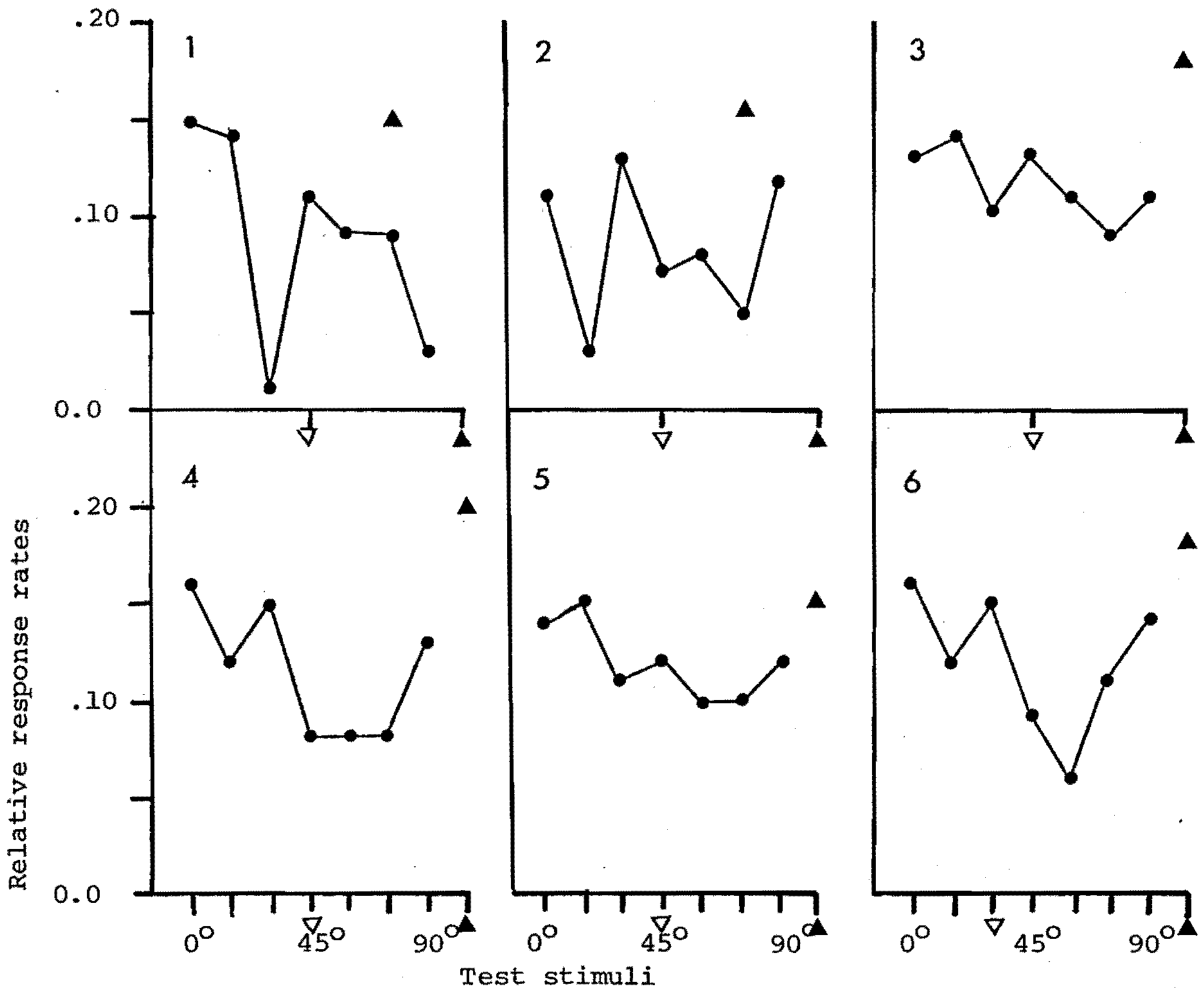
Figures 8.4 and 8.5 give the grouped relative response rates during these tests from each of the six sessions. These grouped data all result in nonsystematic gradients, as would the data from each subject if graphed individually.

4. DISCUSSION

(i) Discrimination training

The development of differential responding to S1 and S2 during discrimination training shown in Figure 8.1 is not unlike that of Figures 6.1 and 7.1, which both show discrimination training

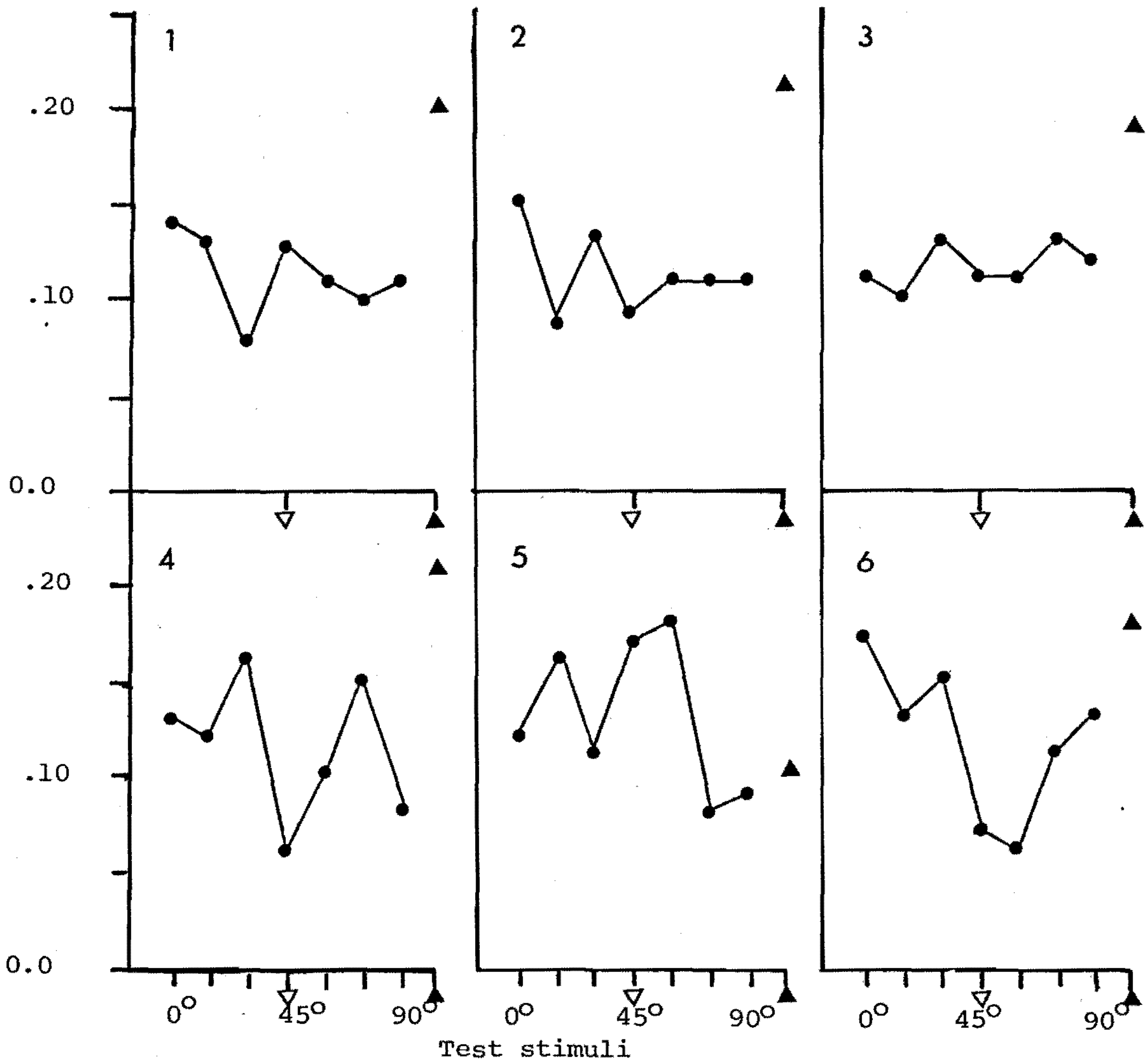
Figure 8.4



▲ S1: blank white key with brightness of 70 lux

▽ S2: 45° white line on black background

Fig. 8.4 Experiment 6: grouped relative response rates of subjects E1 to E4 during six sessions of resistance-to-reinforcement generalization testing along the line orientation dimension around S2.



▲ S1: blank key with brightness of 70 lux

▽ S2: 45° white line on black background

Fig. 8.5 Experiment 6: grouped relative response rates of subjects E5 to E8 during six sessions of resistance-to-reinforcement generalization testing along the line orientation dimension around S2.

responding after an initial stabilising baseline phase. However, the marked increases in response rate to S1 in Experiment 8 cannot be labelled as positive behavioural contrast because of the absence of a prior baseline phase against which to compare these response rates. Nevertheless, the similarities in the discrimination training data of these three experiments suggest that responding in all cases is under the control of the same processes, i.e. that prior baseline training did not impair later discrimination training. However, more systematic research is required in this area. Although most discrimination learning studies have acknowledged the importance of a baseline phase as a within-subject control, there are no clear guidelines about the form this baseline phase should take. Both single-stimulus training and multiple schedules are used, lasting one or two sessions or up to 20. Parametric studies are required to evaluate the effects of pretraining upon later discrimination learning so that factors affecting stimulus control may be more clearly defined and not left at the level of supposition, such as reported by Dickson and Zuehlke (1973), who stated that:

"The failure of the three groups to show a measurable reduction in S-responding is probably due to the extensive amount of single-stimulus pretraining administered prior to the introduction of the multiple schedule."

(p.270)

Dickson and Zuehlke did not test this hypothesis by repeating their experiment without the pretraining.

(ii) Generalization test in extinction

The crucial procedural difference between Experiment 6 and the two immediately preceding experiments was the absence of a baseline training phase in the former, so that none of the subjects had prior excitatory training in the presence of S2. In the first five experiments, pre-discrimination training generalization tests had been administered to provide a baseline against which to compare the gradients obtained after discrimination training. Eliminating both the baseline training and baseline testing in Experiment 6 provided a different control condition in removing a possible influence upon the later testing, viz. prior excitatory experience. Figures 8.2.1 and 8.2.2 present these test findings, which are parallel to those of Figures 6.4 and 7.3 respectively. The results of Experiment 8, that generalization testing around S2 after mult VI-60sec EXT produced U-shaped gradients but after mult VI-60sec VI-60sec(SIG) the gradients were nonsystematic, support the results already obtained in the previous two experiments. This suggests that there had been no differential effect on subsequent testing as a result of the prior excitatory training during the baseline phase. The results of the generalization testing along the line orientation dimension in Experiments 4, 5 and 6 can therefore be regarded as direct measures of the dimensional stimulus control acquired around the two training stimuli, independent of the dimensional control exerted by the other training stimulus and also apparently unaffected by prior excitatory properties of these stimuli.

This conclusion is at odds with some drawn by other researchers investigating the transfer of conditioned excitation or inhibition. Zentall, Collins and Hearst (1971) tested the dimensional stimulus control around S2 along a line orientation dimension. They had two groups of pigeons, which differed in their history of training in the presence of S2 (referred to as S- by Zentall et al). The group exposed to prior excitatory training in the presence of S2 produced U-shaped gradients during testing in extinction, as did the group without this prior excitatory training:

> "... the general shape of gradients around S- during tests in extinction was not greatly affected by prior training on a discrimination in which the final S- served as an S+."
> (p.259)

However, the two groups did differ in the absolute number of responses made in the presence of each test stimulus. Zentall et al discussed these results in terms of the strength of the inhibitory properties of such a stimulus, implying that a previously positive S2 was not as strongly inhibitory as one which had never been associated with reinforcement.

In the present series of experiments, this proposition would be tested by comparing the inhibitory properties of S2 in Experiment 4 with those of S2 following EXT in Experiment 6. The former would be comparable with Zentall et al's P→N group, trained with a "formerly positive S-", and the latter equivalent to their N group, trained with the "always negative S-". Comparison of Figures 6.4 and 8.2.1 does not reveal any differences between the groups in terms of the extent of inhibitory dimensional control around S2. Both groups produce U-shaped gradients, and the amount of variability in the shape of these within each group outweighs any suggestion of a difference between the groups.

Adopting Hearst, Besley and Farthing's (1970) approach that a more direct measure of the inhibitory properties of a stimulus is required, the resistance-to-reinforcement test gradients of these two groups must be compared. If one S2 were more inhibitory than the other, then it would resist the influence of reinforcement more strongly. If Zentall et al's proposition were to be supported, then the gradients of the Experiment 6 group should demonstrate more resistance to reinforcement than the Experiment 4 group. These resistance-to-reinforcement data will be dealt with in part (iv) of this Discussion.

(iii) Generalization test in presence of houselight

The responding of only one of the four birds of the EXT group, E1, was disrupted by the addition of the houselight during the second generalization test in extinction. The other three EXT subjects appear to have either not attended to the houselight or to have treated it as irrelevant to the learned discriminations. The latter is the more likely account, judging from observation of the birds during this test. All four birds showed marked increases in wing flapping, jumping up, and walking around the chamber when the houselight first came on, but this soon subsided in all except E1, which continued to sway between the operant key and the houselight, a behaviour strongly characteristic of all subjects of the SIG group.

While the shapes of the gradients obtained from this test in the SIG group differed little from those shown in Figure 8.2.2, the difference in their actual response patterns has already been noted. Interestingly too, none of the SIG group appeared to make any attempt to approach the food hopper during this test, although their prior experience in the VI-60sec(SIG) component had developed a chain of responses from key-peck to attending to the lit houselight to eating grain from the hopper.

The negatively accelerating response curves of the SIG group during this test point to faster extinction of responding than is usually apparent in generalization tests in extinction. This observation fits in with Marcucella's (1976) analysis of signalled reinforcement as a multiple schedule with two components: one, a stimulus associated with continuous reinforcement i.e. an FR (fixed ratio) 1 schedule, and the other, a stimulus associated with extinction.

Using this analysis, the discrimination training procedure of all SIG subjects, viz. <u>mult</u> VI-60sec VI-60sec(SIG), becomes a three-ply multiple schedule with different amounts of time allotted to each component:

<u>mult</u> VI-60sec EXT FR1

where VI-60sec is associated with S1
EXT is associated with S2 and
FR1 is associated with the compound stimulus of S2-plus-houselight

Such an account of signalled reinforcement has important implications for the comparison of the effects of signalled reinforcement and extinction as discrimination training procedures, which has been the subject of investigation throughout this series of experiments. Marcucella suggested that:

"... the variable responsible for occurrence of contrast when reinforcer availability is signalled in the variable component of <u>mult</u> VI VI schedules ... is the presence of a stimulus correlated with nonreinforcement."

(p.204)

This implies that the difference between the SIG and EXT conditions is illusory, and that the former is itself just a variant of the latter rather than a distinctly different discrimination training procedure. If, in fact, SIG is nothing more than a special case of EXT, then these procedures should produce similar responding in other areas than just the development of positive behavioural contrast. If, during a signalled reinforcement component, S2 alone is associated with EXT, then the dimensional stimulus control it exerts should be the same as that around an S2 associated with EXT proper. The results of this series of experiments show that this is not the case. Furthermore, generalization testing around the compound stimulus of S2-plus-houselight provides an additional test of this analysis of signalled reinforcement. If this compound stimulus functions as one controlling an FR1 schedule, then it would be expected to exert excitatory dimensional stimulus control. However, again this is not the case: the gradients shown in Figure 8.3.2 are not the inverted-U gradients indicative of excitatory dimensional control.

(iv) Resistance-to-reinforcement tests

Analysis of the test results shown in Figures 6.6 and 8.4 provides a comparison of gradients obtained after *mult* VI-60sec EXT training when one of the groups had had prior exposure to *mult* VI-60sec VI-60sec but the other had not. Zentall, Collins and Hearst (1971) reported that comparable resistance-to-reinforcement tests generally supported the results of testing in extinction: both the P→N and N group gradients had minima at S2. They noted that two of their subjects in the P→N group responded more to S2 on the second and third test days, suggesting that the previously positive function of this S2 accounted for the rapidity of this gradient reversal.

Once again, no such difference between the two groups is revealed in this series of experiments:

neither the group nor individual resistance-to-reinforcement gradients show such clear U-shaped gradients, nor is there any clear evidence of gradient reversal, even over four and six days of testing. There are two possibilities that could account for this difference between the results of these experiments and the results obtained by Zentall et al. The first relates specifically to the resistance-to-reinforcement tests. Throughout the current series of experiments there has been a consistently poor correlation between gradients obtained through testing in extinction and as resistance to reinforcement, limiting the power of conclusions that could be drawn from the latter gradients.

The other factor is an important procedural difference between the experiment reported by Zentall et al and the current series. The final discrimination of the P→N group included not only a formerly positive S2 but also a formerly negative S1. The final discrimination of this group was therefore the reverse of the original discrimination. In Experiments 4 and 5, however, only the S2 discrimination was changed between baseline and discrimination training. S1 was associated with VI-60sec in both phases. This does not constitute a reversal of a discrimination, and the inhibitory properties of an S2 following this procedure may differ from those following reversal.

Overall, the results of Experiment 6 confirm those of Experiments 4 and 5, indicating that the prior exposure to _mult_ VI-60sec VI-60sec during baseline training did not materially alter the effects of later discrimination training.

CHAPTER IX

CONCLUSIONS

This series of six experiments looked at two different ways of suppressing responding in one component of a multiple schedule using both intradimensional and inter-dimensional training methods. There have been very few other reports of direct comparisons of these two training methods, and those that have, e.g. Hearst (1969), Klein and Rilling (1974) and Marsh (1972) have concentrated on investigating the relationship between empirically- and theoretically-derived post-discrimination gradients as a measure of the efficacy of Spence's (1937) theory of the algebraic summation of gradients of excitation and inhibition. This approach has provided reasonable support for Spence's theory using the dimensions of line orientation (Hearst, 1969) and wavelength (Marsh, 1972), and in a free-operant avoidance paradigm (Klein and Rilling, 1974) where the dimension used was auditory frequency. Klein and Rilling point out the limitations inherent in attempts to match relative empirical generalization gradients to those which are theoretically derived, because of the lack of direct comparability between proportional and absolute response rates (p.p. 86-87).

The experiments reported by the investigators listed above suggest that the determinants of peak shift and inhibitory dimensional stimulus control are the same. This finding is supported by the results of the current series of experiments: when S2 was correlated with extinction, peak shift occurred following intradimensional training, and U-shaped gradients were obtained around S2 following interdimensional training.

This series of experiments also compared two response suppression methods, and found that while both extinction and signalled reinforcement suppressed responding in S2 and produced positive behavioural contrast in S1, they resulted in consistent differences in later generalization test responding. The SIG procedure did not result in peak shift nor in U-shaped gradients around S2. These differences show that the nature of the control exerted over responding by the stimulus correlated with SIG is different from that exerted by the stimulus correlated with EXT. These results also contradict the interpretation of SIG as merely a variant of EXT, proposed by Griffin and Stewart (1977), Lander (1971), Marcucella (1976) and Thompson and Corr (1974). Marcucella's study demonstrated the development of positive behavioural contrast, a result also achieved in the current study. However, Griffin and Stewart (1977) reported peak shift following signalled reinforcement, a result contradictory to those of Experiments 1 and 2. The form of the signal used by both Marcucella and Griffin and Stewart was different from that of the experiments reported here. Marcucella (1976) signalled reinforcer availability by superimposing a white triangle on the red key which was equivalent to an S2. Griffin and Stewart (1977) signalled reinforcer availability by changing the stimulus on the key from the S2, which was a 30° black line on a white background, to a blank white field. These procedures are quite different from that used in this series of experiments, where the stimulus presented on the key remained totally unchanged and reinforcer availability was signalled by the additional onset of the houselight. While this procedure provided the signal by the addition of a second, separate stimulus, Griffin and Stewart's procedure changed the key stimulus during reinforcer availability, so that their subjects were never reinforced in the presence of S2 (the 30° line), which indeed was therefore correlated with EXT and it is no surprise that some of these subjects later showed peak shift. Even Marcucella's addition of a triangle on to the key may have significantly altered the stimulus so that the subjects perceived this as discretely different from the red key per se. Generalization testing after the discrimination training would have revealed whether the red-alone key was perceived as separate from the red-plus-triangle compound.

An interpretation of SIG as a variant of EXT would also not be compatible with the findings of Green and Rachlin (1977) that pigeons prefer information over no information about the probability of reinforcement. This in turn raises doubts about the various theories accounting for positive behavioural contrast. As de Villiers (1977, p.275) points out, there is a large body of data supporting the view that the strength of a response is directly related to the relative frequency or magnitude of reinforcement for that response. But positive behavioural contrast obtained during _mult_ VI SIG training shows such an analysis to be insufficient, just as are "preference" accounts of behavioural contrast, e.g. Gonzalez and Champlin's (1974) conclusion that:

"... what seems necessary is that the contrasting condition of reinforcement be one that engenders aversiveness in the context in which it is given."
(p.185)

In no sense can the SIG condition used in these experiments be said to be a change for the worse.

These results have significance with respect to the theoretical position espoused by Terrace. He attributes positive behavioural contrast, peak shift and inhibitory dimensional stimulus control to inhibition:

"... the data on hand indicate that those conditions which produce a peak-shift and contrast also produce inhibitory stimulus control."
(Terrace, 1972, p.243)

and also states that:

"... discrimination learning with errors results in contrast, the peak-shift and inhibitory stimulus control."
(Terrace, 1972, p.243)

The results of the SIG groups show the separation of behavioural contrast and peak shift, and behavioural contrast and inhibitory dimensional stimulus control. These three phenomena need not covary: positive behavioural contrast is not a necessary nor sufficient condition for the development of later inhibitory dimensional stimulus control.

What these results do not contradict is the conclusion drawn by Karpicke and Hearst (1975), that:

"A negative correlation between stimulus and reinforcer seems the crucial factor in producing an inhibitory stimulus."
(p.159)

Those conditions that produced peak shift (i.e. discrimination training using EXT in S2) also produced inhibitory dimensional control during later testing in extinction.

Skinner's (1938) view that response suppression is nothing more than a reduction in excitation is not sufficient to account for the results of this series of experiments. The generalization test data show clear differences following response rate reduction in both EXT and SIG. Therefore, while both these procedures could be said to reduce excitation, the differences in dimensional control exerted around S2 after such training indicate that the response rate reduction after EXT cannot be accounted for solely in terms of reduced excitation. These differences appear to require the concept of inhibitory dimensional stimulus control as distinct from an inhibitory stimulus, the distinction clarified by Hearst, Besley and Farthing (1970).

There are some limitations upon such a conclusion being drawn on the basis of these experiments. As discussed in Chapter V with respect to the combined-cues test, Farthing and Hearst (1968), and Hearst et al (1970) cautioned against concluding that a flat gradient indicated the absence of an inhibitory stimulus. Conversely, Couch (1975) suggested that the actual attainment of a U-shaped gradient need not imply inhibitory dimensional control but might represent excitatory control of long inter-response times.

On the whole, however, these results provide further support for Spence's remarkably robust theory. It would now require a further series of tests using other response suppression methods and comparing these using both intra- and interdimensional training. For greater clarification of the occurrence, magnitude and stability of positive behavioural contrast, an added control group not given differential training, should be used. This requirement has already been discussed by Gonzalez and Champlin (1974) who criticised the convention of measuring contrast solely on a within-subject basis.

Further experimentation within the field of discrimination learning needs to be directed, not at attempting to provide a single account for all the phenomena subsumed under the term of stimulus control, but rather at identifying the relationships between specific behaviours and circumstances.

REFERENCES

AMSEL, A. (1958) The role of frustrative non-reward in noncontinuous reward situations. Psychol. Bull., 55, 102-119.

AMSEL, A. (1962) Frustrative non-reward in partial reinforcement and discrimination learning. Psychol. Rev., 69, 306-328.

BALDOCK, M.D. (1970) Positive behavioural contrast: response suppression and the signalling of reinforcement. Christchurch, University of Canterbury. 98 p. (Thesis: M.A.: Psychology).

BALDOCK, M.D., and BLAMPIED, N.M. (1970) Control by stimuli associated with response rate reduction. Paper read at annual meeting of the New Zealand Psychological Society, Otago University, Dunedin.

BARON, M.R., and BRESNAHAN, E.L. (1969) The effect of chromatic surround upon generalization along an angularity dimension in pigeons. Psychon. Sci., 15, 9-10.

BILBREY, J., and WINOKUR, S. (1974) Behavioral contrast in a second-order multiple schedule of reinforcement. Bull. Psychon. Soc., 4(3), 206-208.

BLAMPIED, N.M. (1972) Contrast, preference and signalled reinforcement. Paper read at the annual meeting of the New Zealand Psychological Society, Massey University, Palmerston North.

BLOOMFIELD, T.M. (1967) Behavioral contrast and relative reinforcement frequency in two multiple schedules. J. Exp. Anal. Behav., 10, 151-158.

BLUE, S., SHERMAN, J.G., and PIERREL, R. (1971) Differential responding as a function of auditory stimulus intensity without differential reinforcement. J. Exp. Anal. Behav., 15, 371

BOAKES, R.A. (1972) Frequency of houselight interruption as a dimension for inhibitory generalization testing. Psychon. Sci., 26(5), 249-251.

BOAKES, R.A., HALLIDAY, M.S., and MOLE, J.S. (1976) Successive discrimination training with equated reinforcement frequencies: failure to obtain behavioral contrast. J. Exp. Anal. Behav., 26(1), 65-78.

BONEAU, C.A., and HONIG, W.K. (1964) Opposed generalization gradients based upon conditional discrimination training. J. Exp. Psychol., 66, 89-93.

BOWER, G., McLEAN, J., and MEACHAM, J. (1966) Value of knowing when reinforcement is due. J. Comp. Physiol. Psychol., 62, 184-192.

BRETHOWER, D.M., and REYNOLDS, G.S. (1962) A facilitative effect of punishment on unpunished behavior. J. Exp. Anal. Behav., 5, 191-199.

BROWN, J.S. (1965) Generalization and discrimination. In D.L. Mostofsky(Ed.), Stimulus Generalization. Stanford: Stanford University Press.

BROWN, P.L., and JENKINS, H.M. (1968) Auto-shaping of the pigeon's key-peck. J. Exp. Anal. Behav., 11(1), 1-8.

BROWNSTEIN, A.J., and HUGHES, R.G. (1970) The role of response suppression in behavioral contrast: signaled reinforcement. Psychon. Sci., 18(1), 50-52.

BROWNSTEIN, A.J., and NEWSOM, C. (1970) Behavioral contrast in multiple schedules with equal reinforcement rates. Psychon Sci., 18(1), 25-26.

CATANIA, A.C., SILVERMAN, P.J., and STUBBS, D.A. (1974) Concurrent performances: Stimulus-control gradients during schedules of signalled and unsignalled concurrent reinforcement. J. Exp. Anal. Behav., 21, 99-108.

COATES, T.J. (1972) The differential effects of punishment and extinction on behavioral contrast. Psychon. Sci., 27, 146-148.

CORBALLIS, M.C., and BEALE, I.L. (1970) Bilateral symmetry and behavior. Psychol. Rev., 77, 451-464.

COUCH, J.V. (1975) Behavioral contrast and inhibitory stimulus control. An. Learn.& Behav., 3(4), 347-358.

DAVIS, J.M. (1971) Testing for inhibitory stimulus control with S^- superimposed on S^+. J. Exp. Anal. Behav., 15, 365-369.

DAWLEY, J.M., and DENNY, M.R. (1974) Postdiscrimination generalization as a function of testing procedure: steep inhibitory gradients. Bull. Psychon. Soc., 3(5B), 380-382.

de VILLIERS, P. (1977) Choice in concurrent schedules and a quantitative formulation of the Law of Effect. Chapter 9 in W.K. Honig and J.E.R. Staddon (Eds.), Handbook of Operant Behavior, Prentice Hall, New Jersey.

DEUTSCH, J.A. (1967) Discrimination learning and inhibition. Science, 156, 988. (Technical comment).

DICKSON, J.F., and ZUEHLKE, T.E. (1973) Discrimination learning as a function of component duration. Bull. Psychon. Soc., 2(5A), 268-270.

DYSART, J., MARX, M.H., McLEAN, J., and NELSON, J.A. (1974) Peak shift as a function of multiple schedules of reinforcement. J. Exp. Anal. Behav., 22, 463-470.

FARTHING, G.W. (1972) Overshadowing in the discrimination of successive compound stimuli. Psychon. Sci., 28, 29-32.

FARTHING, G.W., and HEARST, E. (1968) Generalization gradients of inhibition after different amounts of training. J. Exp. Anal. Behav., 11, 743-752.

FARTHING, G.W., and HEARST, E. (1972) Stimulus generalization and discrimination along the click-frequency (flutter) continuum in pigeons. Percept. and Psychophys., 12(2A), 176-182.

FERSTER, C.B., and SKINNER, B.F. (1957) Schedules of Reinforcement. Appleton-Century-Crofts, New York.

FLESHLER, M., and HOFFMAN, H.S. (1962) A progression for generating variable-interval schedules. J. Exp. Anal. Behav., 5, 529-530.

FREEMAN, B.J. (1971) Behavioral contrast: reinforcement frequency on response suppression? Psychol. Bull., 75(5), 347-356.

FREEMAN, F., and THOMAS, D.R. (1967) Attention vs. cue utilization in generalization testing. Paper presented at Midwestern Psychological Association, Chicago.

GAMZU, E., and SCHWARTZ, B. (1973) The maintenance of key pecking by stimulus-contingent and response-independent food presentation. J. Exp. Anal. Behav., 19, 65-72.

GAMZU, E., and WILLIAMS, D.R. (1971) Classical conditioning of a complex skeletal response. Science, 171, 923-925.

GELLERMAN, L.W. (1933) Chance order of alternating stimuli in visual discrimination experiments. Pedagogical Seminary and Journal of Genetic Psychology, 42, 206-208.

GONZALEZ, R.C., and CHAMPLIN, G, (1974) Positive behavioral contrast, negative simultaneous contrast and their relation to frustration in pigeons. J. Comp. Physiol. Psychol., 87(1), 173-187.

GREEN, L., and RACHLIN, H. (1977) Pigeon's preferences for stimulus inforamtion: effects of amount of inforamtion. J. Exp. Anal. Behav., 27(2), 255-263.

GRIFFIN, P., and COOPER, A.M. (1971) Behavioral contrast resulting from a change in sucrose concentration. Psychon. Sci., 24, 2-3.

GRIFFIN, P ., and STEWART, D.J. (1977) Line-orientation generalization following signalled reinforcer training. J. Exp. Anal. Behav., 27(1), 151-160.

GRUSEC, T. (1968) The peak shift in stimulus generalization: equivalent effects of errors and non-contingent shock. J. Exp. Anal. Behav., 11, 39-49.

GUTTMAN, N. (1959) Generalization gradients around stimuli associated with different reinforcement schedules. J. Exp. Psychol., 58, 335-340.

GUTTMAN, N., and KALISH, H.I. (1956) Discriminability and stimulus generalization. J. Exp. Psychol., 51, 79-88.

GUTTMAN, A., SUTTERER, J.R., and BRUSH, F.R. (1975) Positive and negative behavioral contrast in the rat. J. Exp. Anal. Behav., 23, 377-384.

HALLIDAY, M.S., and BOAKES, R.A. (1972) Discrimination involving response-independent reinforcement: implications for behavioural contrast. In R.A. Boakes and M.S. Halliday(Eds.), Inhibition and Learning. Academic Press, London. Pp. 73-97.

HALLIDAY, M.S., and BOAKES, R.A. (1974) Behavioral contrast without response rate reduction. J. Exp. Anal. Behav., 22, 453-462.

HANSON, H.M. (1959) Effects of discrimination training on stimulus generalization. J. Exp. Psychol., 58, 321-334.

HEARST, E. (1968) Discrimination learning as the summation of excitation and inhibition. Science, 162, 1303-1306.

HEARST, E. (1969a) Excitation, inhibition and discrimination learning. In N.J. Mackintosh and W.K. Honig(Eds.), Fundamental Issues in Associative Learning. Dalhousie University Press, Halifax. Pp. 1-41. (a)

HEARST, E. (1969b) Aversive conditioning and external stimulus control. In B.A. Cambell and R.M. Church (Eds.), Punishment and Aversive Behavior. Appleton-Century-Crofts, New York. Pp. 235-277. (b)

HEARST, E. (1971) Differential transfer of excitatory versus inhibitory pretraining to intradimensional discrimination learning in pigeons. J. Comp. Physiol. Psychol., 75(2), 206-215.

HEARST, E. (1972) Some persistent problems in the analysis of conditioned inhibition. In R.A. Boakes and M.S. Halliday(Eds.), Inhibition and Learning. Academic Press, London. Pp. 5-39.

HEARST, E., BESLEY, S., and FARTHING, G.W. (1970) Inhibition and the stimulus control of operant behavior. J. Exp. Anal. Behav., 14, 373-409.

HEARST, E., and KORESKO, M.B. (1968) Stimulus generalization and amount of prior training on variable-interval reinforcement. J. Comp. Physiol. Psychol., 66, 133-138.

HEARST, E., KORESKO, M.B., and POPPEN, R. (1964) Stimulus generalization and the response-reinforcement contingency. J. Exp. Anal. Behav., 7, 369-380.

HEARST, E., TAUS, S.E., and KORESKO, M.B. (1971) Generalization gradients obtained after continuous reinforcement of an operant response. Psychon. Sci., 24(5), 205-206.

HEMMES, N.S. (1973) Behavioral contrast in pigeons depends upon the operant. J. Comp. Physiol. Psychol., 85, 171-178.

HIROTA, T.T., and CLARKSON, T.A. (1973) Stimulus generalization following intradimensional discrimination training: between and within test comparisons. Bull. Psychon. Soc., 2(1), 3-5.

HONIG, W.K., and BEALE, I.L. (1976) Stimulus duration as a measure of stimulus generalization. J. Exp. Anal. Behav., 25(2), 209-217.

HONIG, W.K., BONEAU, C.A., BURSTEIN, K.R., and PENNYPACKER, H.S. (1963) Positive and negative generalization gradients obtained after equivalent training conditions. J. Comp. Physiol. Psychol., 56, 111-116.

HULL, C.L. (1929) A functional interpretation of the conditional reflex. Psychol. Rev., 36, 495-511.

HULL, C.L. (1949) Stimulus intensity dynamism (V) and stimulus generalization. Psychol Rev., 56, 67-76.

JENKINS, H.M. (1965) Generalization gradients and the concept of inhibition. In D.I. Mostofsky(Ed.), Stimulus Generalization. Stanford University Press, Stanford. Pp. 55-61.

JENKINS, H.M., and HARRISON, R.H. (1962) Generalization gradients of inhibition following auditory discrimination learning. J. Exp. Anal. Behav., 5, 435-441.

KARPICKE, J., and HEARST, E. (1975) Inhibitory control and errorless discrimination learning. J. Exp. Anal. Behav., 23(2), 159-166.

KELLER, J.V. (1970) Behavioral contrast under multiple delays of reinforcement. Psychon. Sci., 20, 257-258.

KELLER, K. (1974) The role of elicited responding in behavioral contrast. J. Exp. Anal. Behav., 21, 249-257.

KLEIN, M., and RILLING, M. (1974) Generalization of free-operant avoidance behavior in pigeons. J. Exp. Anal. Behav., 21, 75-88.

KODERA, T., and RILLING, M. (1976) Procedural antecedents of behavioral contrast: a re-examination of errorless learning. J. Exp. Anal. Behav., 25(1), 27-42.

LANDER, D. (1970) Interactions in operant discrimination. Unpublished paper.

LANDER, D.G. (1971) Stimulus control following response reduction with signaled reinforcement. Psychon. Sci. 23, 365-367.

LEWIS, P., LEWIN, L., MUEHLEISEN, P., and STOYAK, M. (1974) Preference for signalled reinforcement. J. Exp. Anal. Behav., 22, 153-160.

LYONS, J. (1969a) Stimulus generalization as a function of discrimination learning with and without errors. Science, 163, 490-491. (a)

LYONS, J., and THOMAS, D.R. (1967) Effects of interdimensional training on stimulus generalization: II. Within subjects design. J. Exp. Psychol., 75, 572-274.

MACKINTOSH, N.J. (1974) The Psychology of Animal Learning. Academic Press, London.

MALONE, J.C., and STADDON, J.E.R. (1973) Contrast effects in maintained generalization gradients. J. Exp. Anal. Behav., 19(1), 167-179.

MARCUCELLA, H. (1976) Signalled reinforcement and multiple schedules. J. Exp. Anal. Behav., 26(2), 199-206.

MARINER, R.W., and THOMAS, D.R. (1969) Reinforcement duration and the peak shift in post-discrimination gradients. J. Exp. Anal. Behav., 12(5), 759-766.

MARSH, G. (1972) Prediction of the peak shift in pigeons from gradients of excitation and inhibition. J. Comp. Physiol, Psychol., 81(2), 262-266.

NEVIN, J.A., and SHETTLEWORTH, S.J. (1966) An analysis of contrast effects in multiple schedules. J. Exp. Anal. Behav., 9, 305-315.

NEWMAN, F.L., and BARON, M.R. (1965) Stimulus generalization along the dimension of angularity. J. Comp. Physiol. Psychol., 60, 59-63.

NEWMAN, F.L., and BENEFIELD, R.L. (1968) Stimulus control, cue utilization and attention. Effects of discrimination training. J. Comp. Physiol. Psychol., 66, 101-104.

NICHOLSON, J.N., and GRAY, J.A. (1972) Peak shift, behavioural contrast and stimulus generalization as related to personality and development in children. Brit. J. Psychol., 63, 47-62.

O'BRIEN, F. (1968) Sequential contrast effects with human subjects. J. Exp. Anal. Behav., 11, 537-542.

PARKER, B.K. (1973) Effects of blackout position and discrimination training initiation on dimensional control by S^- in pigeons. J. Comp. Physiol. Psychol., 84(2), 324-331.

PAVLOV, I.P. (1927) Conditioned Reflexes. Oxford University Press, Oxford.

PERT, A., and GONZALEZ, R.C. (1974) Behavior of the turtle (Chrysemys picta picta) in simultaneous, successive, and behavioral contrast situations. J. Comp. Physiol Psychol., 87(3), 526-538.

PETERSON, N. (1962) Effect of monochromatic rearing on the control of responding by wavelength. Science. 136, 774-775.

PLISKOFF, S.S., and GREEN, D. (1972) Effects on concurrent performances of a stimulus correlated with reinforcer availability. J. Exp. Anal. Behav., 17(2), 221-227.

PURTLE, R.B. (1973) Peak shift: a review. Psychol. Bull., 80, 408-421.

REBERG, D., and BLACK, A.H. (1969) Compound testing of individually conditioned stimuli as an index of excitatory and inhibitory properties. Psychon. Sci., 17(1), 30-31.

REYNOLDS, G.S. (1961) Behavioral contrast. J. Exp. Anal. Behav., 4, 57-71.

REYNOLDS, G.S., and CATANIA, A.C. (1961) Behavioral contrast with fixed-interval and low-rate reinforcement. J. Exp. Anal. Behav., 4, 387-392.

REYNOLDS, G.S., and LIMPO, A.J. (1968) On some causes of behavioral contrast. J. Exp. Anal. Behav., 11, 543-547.

RICCI, J.A. (1973) Key pecking under response-independent food presentation after long simple and compound stimuli. J. Exp. Anal. Behav., 19, 509-516.

RICHARDS, R.W. (1972) Reinforcement delay: some effects on behavioral contrast. J. Exp. Anal. Behav., 17(3), 381-394.

RICHARDS, R.W. (1974) Inhibitory stimulus control and the magnitude of delayed reinforcement. J. Exp. Anal. Behav., 21(3), 501-509.

RICHARDS, R.W. (1975) Reinforcement delay, behavioral contrast, and inhibition. Psychol. Record, 25, 281-291.

RILLING, M. (1977) Stimulus control and inhibitory processes. Chapter 15 in W.K. Honig and J.E.R. Staddon (Eds.), Handbook of Operant Behavior. Prentice Hall, New Jersey. Pp. 432-480.

RILLING, M., ASKEW, H.R., AHLSKOG, J.E., and KRAMER, T.J. (1969) Aversive properties of the negative stimulus in a successive discrimination. J. Exp. Anal. Behav., 12(6), 917-932.

RILLING, M., CAPLAN, H.J., HOWARD, R.C., and BROWN, C.H. (1975) Inhibitory stimulus control following errorless discrimination learning. J. Exp. Anal. Behav., 24(2), 121-133.

ROSEN, A.P., and TERRACE, H.S. (1975) On the minimal conditions for the development of a peak shift and inhibitory stimulus control. J. Exp. Anal. Behav., 23(3), 385-414.

SADOWSKY, S. (1973) Behavioral contrast with timeout, blackout, or extinction as the negative condition. J. Exp. Anal. Behav., 19(3), 499-507.

SCHOENFELD, W.N., CUMMING, W.W., and HEARST, E. (1956) On the classification of reinforcement schedules. Proc. National Acad. of Sciences, 42, 563-570.

SELEKMAN, W. (1973) Behavioral contrast and inhibitory stimulus control as related to extended training. J. Exp. Anal. Behav., 20(2), 245-252.

SKINNER, B.F. (1938) The Behavior of Organisms. Appleton-Century-Crofts, New York.

SKINNER, B.F. (1950) Are theories of learning necessary? Psychol. Rev., 57, 193-216.

SLOANE, H.N. (1964) Stimulus generalization along a light flicker rate continuum after discrimination training with several S^-s. J. Exp. Anal. Behav., 7(3), 217-222.

SLOANE, H.N. (1966) Some effects of light flicker rate on the pigeon. Psychon. Sci., 4, 119-120.

SMITH, M.H., and HOY, W.J. (1954) Rate of response during operant discrimination. J. Exp. Psychol., 48, 259-264.

SPENCE, K.W. (1937) The differential response in animals to stimuli varying within a single dimension. Psychol. Rev., 44, 430-444.

STADDON, J.E.R. (1969) Inhibition and the operant. J. Exp. Anal. Behav., 12(3), 481-487.

SWITALSKI, R.W., LYONS, J., and THOMAS, D.R. (1966) Effects of interdimensional training on stimulus generalization. J. Exp. Psychol., 72, 661-666.

TAUS, S.E., and HEARST, E. (1972) Operant discrimination learning after different amounts of reinforced pretraining to the positive stimulus. J. Exp. Psychol., 94(1), 33-40.

TERRACE, H.S. (1966a) Stimulus control. In W.K.Honig (Ed.), Operant Behavior: Areas of Research and Application. Appleton-Century-Crofts, New York. Pp. 271-344.(a)

TERRACE, H.S. (1966b) Discrimination learning and inhibition. Science, 154, 1677-1680. (b)

TERRACE, H.S. (1968) Discrimination learning, the peak shift and behavioral contrast. J. Exp. Anal. Behav., 11(6), 727-741.

TERRACE, H.S. (1971) Escape from S$^-$. Learning and Motivation, 2, 148-163.

TERRACE, H.S. (1972) By-products of discrimination learning. In G.H. Bower(Ed.), The Psychology of Learning and Motivation, Vol. 5. Academic Press, New York. Pp. 195-265.

THOMAS, D.R. (1962) The effects of drive and discrimination training on stimulus generalization. J. Exp. Psychol., 64, 24-28.

THOMAS, D.R., and BURR, D.E.S. (1969) Stimulus generalization as a function of the delay between training and testing procedures: a reevaluation. J. Exp. Anal. Behav., 12(1), 105-109.

THOMAS, D.R., and KING, R.A. (1959) Stimulus generalization as a function of level of motivation. J. Exp. Psychol., 57, 323-328.

THOMAS, D.R., and LYONS, J. (1968) Further evidence of a sensory-tonic interaction in pigeons. J. Exp. Anal. Behav., 11(2), 167-171.

THOMAS, D.R., and WILLIAMS, J.L. (1963) A further study of stimulus generalization following three-stimulus discrimination training. J. Exp. Anal. Behav., 6, 171-176.

THOMAS, G.V., and CAMERON, G.N. (1974) Response rate, reinforcement frequency, and behavioral contrast. J. Exp. Anal. Behav., 22(2), 427-432.

THOMPSON, D.M., and CORR, P.B. (1974) Behavioral parameters of drug action: signalled and response-independent reinforcement. J. Exp. Anal. Behav., 21(1), 151-158

TOMIE, A., DAVITT, G.A., and ENGBERG, L.A. (1976) Stimulus generalization of auto-shaped keypecking following interdimensional and extradimensional training. Learn. and Motivation, 7, 240-253.

TRACY, W.K. (1970) Wavelength generalization and preference in monochromatically reared ducklings. J. Exp. Anal. Behav., 13, 163.

VIETH, A., and RILLING, M. (1972) Comparison of time-out and extinction as determinants of behavioral contrast: an anlysis of sequential effects. Psychon. Sci., 27(5), 281-282.

WELLS, M.J., and YOUNG, J.Z. (1970) Stimulus generalization in the Tactile System of Octopus. Journal of Neurobiology, 2, 31-46.

WEISMAN, R.G. (1969) Some determinants of inhibitory stimulus control. J. Exp. Anal. Behav., 12(3), 443-450.

WEISMAN, R.G. (1970) Determinants of inhibitory stimulus control. In J.H. Reynierse (Ed.), Current Issues in Animal Learning. University of Nebraska Press, Lincoln. Pp. 295-309.

WEISMAN, R.G., and PALMER, J.A., (1969) Factors influencing inhibitory stimulus control: discrimination training and prior non-differential reinforcement. J. Exp. Anal. Behav., 12(2), 229-237.

WESTBROOK, R.F. (1973) Failure to obtain positive contrast when pigeons press a bar. J. Exp. Anal. Behav., 20(3), 499-510.

WHITE, K.G. (1972) Choice and frequency measures of stimulus control following simultaneous discrimination. Psychon. Sci., 27(1), 15-17.

WHITE, K.G., and THOMAS, D.R. (1979) Topographically tagged stimulus control: mainained generalization and stimulus-specific gradients. Bull. Psychon. Soc., 13(5), 275-278.

WILKIE, D.M. (1971) Delayed reinforcement in a multiple schedule. J. Exp. Anal. Behav., 16(2), 233-239.

WILKIE, D.M. (1972) The peak shift and behavioral contrast: effects of discrimination training with delayed reinforcement. Psychon. Sci., 26(5), 257-258.

WILKIE, D.M. (1973) Signalled reinforcement in multiple and concurrent schedules. J. Exp. Anal. Behav., 20(1), 29-36.

WILKIE, D.M. (1974) Stimulus control of responding during a fixed interval reinforcement schedule. J. Exp. Anal. Behav., 21(3), 425-432.

WILKIE, D.M., and MASSON, M.E. (1976) Attention in the pigeon: a reevaluation. J. Exp. Anal. Behav., 26(2), 207-212.

WILLIAMS, D.R., and WILLIAMS, H. (1969) Auto-maintainance in the pigeon: sustained pecking despite contingent non-reinforcement. J. Exp. Anal. Behav., 12, 511-520.

WILTZ, R.A., BOREN, J.J., MOERSCHBAECHER, J.M., CREED, T.L., and SCHROT, J.F. (1973) Generalization gradients and combined-stimulus control after equal training with two related stimuli. Psychol. Reports, 32, 1003-1008.

WILTZ, R.A., BOREN, J.J., MOERSCHBAECHER, J.M., CREED, T.L., and SCHROT, J.F. (1974) Generalization gradients and combined-stimulus control after equal training with two related stimuli: II. Effects of "errorless" training. III. Effects of chlorpromazine. Psychol. Record, 24, 449-468.

WINTON, A.S.W. (1973) Peak shift following simultaneous discrimination training. Auckland, University of Auckland. (Thesis: Ph.D.: Psychology).

WINTON, A.S.W. (1975) Peak shift following simultaneous discriminations. J. Exp. Anal. Behav., 24(3), 303-310.

YARCZOWER, M. (1970) Behavioral contrast and inhibitive stimulus control. Psychon. Sci., 18(1), 1-3.

YARCZOWER, M., and CURTO, K. (1972) Stimulus control in pigeons after extended discriminative training. J. Comp. Physiol. Psychol., 80(3), 484-489.

YARCZOWER, M., and EVANS, G. (1974) "Combined cue" test of conditioned inhibition in pigeons. J. Comp. Physiol. Psychol., 87(2), 261-266.

YARCZOWER, M., GOLLUB, L.R., and DICKSON, J.F. (1968) Some effects of discriminative training with equated frequency of reinforcement. J. Exp. Anal. Behav., 11(4), 415-423.

ZENTALL, T. (1972) Attention in the pigeon: novelty effects and testing with compounds. Psychon. Sci., 27(1), 31-32.

ZENTALL, T., COLLINS, N., and HEARST, E. (1971) Generalization gradients around a formerly positive S^-. Psychon. Sci., 22(5), 257-259.

APPENDIX I

EXPERIMENT 1:-

mean number of responses per minute for the final six sessions of baseline training (MULT VI-60sec VI-60sec) in both components.

Subject	S1	S2
J1	66	69
J2	114	118
J3	94	93
J4	78	77
J5	96	92
J6	66	73

Experiment 1: <u>Generalization test data:</u> (line orientation dimension)

Response/minute

(a) Pre-discrimination training

Test Stimulus	J1	J2	J3	J4	J5	J6
			Subject			
0^{o}	67	115	96	88	97	61
15^{o}	70	123	111	98	116	75
∝ 30^{o}	63	126	84	102	105	67
45^{o}	74	152	102	76	116	55
∝ 60^{o}	65	139	83	78	107	56
75^{o}	70	124	84	96	108	58
90^{o}	71	119	89	90	99	55

(b) Post-discrimination training

0^{o}	41	60	72	126	0	110
15^{o}	68	104	0	14	6	123
∝ 30^{o}	79	159	6	1	0	84
45^{o}	52	93	0	4	54	26
∝ 60^{o}	24	57	141	185	91	2
75^{o}	66	93	2	15	141	9
90^{o}	67	96	17	58	118	9

∝ = training stimuli (in either S1 or S2)

APPENDIX II

EXPERIMENT 2:-

Baseline training data:

mean number of responses per minute for the final six sessions of baseline training (MULT VI-60sec VI-60sec) in both components.

Subject	S1	S2
A1	45	50
A2	33	39
A3	52	51
A4	92	92
A5	62	66
A6	100	98
A7	63	60
A8	99	102

Experiment 2: Generalization test data: (flicker rate dimension)

Responses/minute

(a) Pre-discrimination training

	Subject							
Test Stimulus	A1	A2	A3	A4	A5	A6	A7	A8
No 1	53	36	54	103	60	103	64	102
∝ 2	47	34	53	98	69	102	67	104
3	61	42	56	106	73	108	55	110
4	46	34	57	109	61	103	70	100
5	44	38	53	105	69	101	42	105
6	49	43	54	108	71	99	55	97
∝ 7	45	41	57	108	59	95	61	97

(b) Post-discrimination training test:

1	48	20	71	105	164	169	36	21
∝ 2	45	17	88	102	107	146	82	59
3	49	38	65	97	93	115	122	102
4	53	43	65	96	86	90	144	103
∝ 5	60	47	42	100	72	91	174	118
6	71	57	41	91	46	80	178	154
7	51	41	48	94	55	66	190	165

∝ = training stimuli (i.e. either S1 or S2)

APPENDIX III

EXPERIMENT 3:-

<u>Baseline training data</u>:

mean number of responses per minute for the final six sessions of baseline training (VI-60sec) in S1 component.

(S1 = yellow blank key)

subject:	B1	B2	B3	B4	B5	B6	B7	B8
Responses/minute:	52	64	58	60	43	94	60	40

<u>Generalization test data</u>: (line orientation dimension)

(1) Pre-discrimination training generalization test:

	Subjects							
Test Stimuli	B1	B2	B3	B4	B5	B6	B7	B8
α S1 (yellow key)	64	93	96	89	63	126	50	48
90°	4	77	73	76	47	91	52	26
75°	2	51	61	49	30	56	34	18
60°	4	85	71	68	47	96	44	19
α 45°	3	52	57	48	30	50	18	10
30°	1	79	66	50	39	85	45	29
15°	0	80	66	67	45	66	44	28
0°	10	40	64	49	41	52	25	18

Experiment 3:

(2) Post discrimination training generalization test:

Test Stimuli	Subjects B1	B2	B3	B4	B5	B6	B7	B8
$\propto$ S1(yellow)	147	88	71	89	73	141	115	78
90^{o}	0	64	46	24	35	25	25	34
75^{o}	0	74	36	23	70	29	18	50
60^{o}	2	64	57	28	24	8	23	35
45^{o}	0	66	55	29	31	14	30	44
30^{o}	0	26	35	27	33	13	41	33
15^{o}	0	62	30	27	58	18	52	31
0^{o}	0	50	47	29	22	14	43	34

(3) Combined cues generalization tests:

(a) Where S1 (i.e. yellow background) is added cue:

	subject							
Test Stimulus	B1	B2	B3	B4	B5	B6	B7	B8
90^{o}(+S1)	114	72	54	70	68	106	71	66
75^{o}	111	62	36	80	69	103	84	80
60^{o}	123	80	36	70	72	95	79	70
45^{o}	132	70	53	73	69	100	75	86
30^{o}	131	50	32	67	51	104	74	67
15^{o}	125	71	67	67	64	107	81	74
S1 alone	110	47	64	70	65	81	71	66

(b) Where green background is added cue:

90^{o}(+ green)	0	38	12	32	2	3	2	11
75^{o}	0	49	0	15	1	1	1	3
60^{o}	0	50	39	43	12	14	2	14
45^{o}	0	13	16	13	6	1	3	10
30^{o}	0	67	8	25	3	2	0	1
15^{o}	0	58	49	13	10	2	3	8
0^{o}	0	69	0	12	0	2	3	2
green alone	0	55	24	10	3	1	1	2

(4) Resistance to Reinforcement Generalizaton Tests:

(line orientation)

	SESSION ONE				SESSION TWO			
Test Stimulus	B1	B2	B3	B4	B1	B2	B3	B4
90°	20	64	49	57	70	49	45	42
75°	35	65	45	53	71	67	61	51
60°	10	70	51	48	68	63	47	50
$\propto$ 45°	15	65	45	48	85	65	55	58
30°	10	61	49	94	67	61	51	49
15°	15	66	40	47	65	57	47	53
0°	29	64	52	47	101	58	57	51
$\propto$ S1	111	77	71	62	114	68	68	88

	SESSION THREE				SESSION FOUR			
Test Stimulus	B1	B2	B3	B4	B1	B2	B3	B4
90°	90	70	66	71	101	63	53	73
75°	97	73	65	74	111	80	68	75
60°	105	61	64	69	108	75	64	73
$\propto$ 45°	93	81	69	80	109	65	42	62
30°	99	69	66	64	117	72	69	67
15°	97	68	69	67	95	62	52	63
0°	110	68	68	68	122	77	69	73
$\propto$ S1	125	69	73	79	102	73	62	85

	SESSION FIVE				SESSION SIX			
Test Stimulus	B1	B2	B3	B4	B1	B2	B3	B4
90°	111	70	69	67	117	76	53	76
75°	117	70	73	69	124	75	67	71
60°	114	72	53	78	119	75	72	73
$\propto$ 45°	96	74	72	73	122	75	75	75
30°	118	68	55	72	122	68	65	82
15°	109	71	61	73	112	71	71	80
0°	104	80	63	82	109	79	62	75
$\propto$ S1	94	74	74	92	117	79	65	90

	SESSION SEVEN				SESSION EIGHT			
Test Stimulus	B1	B2	B3	B4	B1	B2	B3	B4
90°	96	76	68	76	104	81	64	96
75°	112	83	68	83	93	73	65	84
60°	115	80	68	80	99	75	68	90
$\propto$ 45°	104	71	63	78	96	78	63	90
30°	92	71	69	78	75	84	67	76
15°	104	80	65	80	95	82	63	81
0°	123	73	62	77	96	69	66	87
$\propto$ S1	108	79	68	84	103	68	80	97

SESSION NINE

Test Stimulus	B1	B2	B3	B4
90^{o}	100	63	70	84
75^{o}	73	77	62	86
60^{o}	92	76	66	83
∝ 45^{o}	86	75	64	75
30^{o}	88	71	65	78
15^{o}	98	67	62	82
0^{o}	94	68	65	80
∝ S1	93	70	75	88

(b) EXT group:

	SESSION ONE				SESSION TWO			
Test Stimulus	B5	B6	B7	B8	B5	B6	B7	B8
90^{o}	58	2	46	48	45	40	54	69
75^{o}	52	3	48	54	48	31	69	85
60^{o}	55	1	51	48	48	56	62	82
∝ 45^{o}	42	2	52	47	47	26	71	82
30^{o}	53	121	77	52	53	25	73	68
15^{o}	40	2	44	71	37	35	41	65
0^{o}	59	1	55	58	41	24	65	73
∝ S1	43	2	40	73	39	121	69	74

	SESSION THREE				SESSION FOUR			
Test Stimulus	B5	B6	B7	B8	B5	B6	B7	B8
90°	51	79	71	75	69	77	76	76
75°	55	77	79	75	61	74	78	79
60°	58	75	68	71	60	84	84	73
∝ 45°	52	73	71	82	54	74	62	75
30°	56	60	68	75	61	86	79	70
15°	54	59	77	82	73	85	82	88
0°	53	74	71	78	62	73	85	71
∝ S1	47	103	76	71	64	113	75	68

	SESSION FIVE				SESSION SIX			
Test Stimulus	B5	B6	B7	B8	B5	B6	B7	B8
90°	64	86	84		52	103	81	63
75°	57	91	75		53	94	82	63
60°	64	85	73		51	86	78	59
∝ 45°	61	77	77		50	83	80	59
30°	61	87	82	no data	61	81	77	64
15°	64	75	79		53	81	82	57
0°	57	76	82		56	85	82	57
∝ S1	57	114	75		53	116	90	53

SESSION SEVEN / SESSION EIGHT

Test Stimulus	B5	B6	B7	B8	B5	B6	B7	B8
90^{O}	62	86	84	68	59	101	75	59
75^{O}	67	87	76	62	61	92	78	69
60^{O}	65	83	78	60	64	104	77	57
$\propto$ 45^{O}	69	76	81	74	55	97	78	61
30^{O}	65	85	76	60	58	95	79	57
15^{O}	70	83	76	51	67	101	83	57
0^{O}	68	84	85	54	65	93	70	72
$\propto$ S1	55	94	79	63	51	104	81	50

SESSION NINE

Test Stimulus	B5	B6	B7	B8
90^{O}	63	101	86	54
75^{O}	58	89	78	45
60^{O}	60	87	77	49
$\propto$ 45^{O}	54	89	81	53
30^{O}	59	90	80	46
15^{O}	55	92	73	53
0^{O}	61	92	79	46
$\propto$ S1	56	131	76	53

(5) Second Generalization Test in Extinction

Test Stimuli	Subjects B1	B2	B3	B4	B5	B6	B7	B8
60°	78	38	21	50	43	41	67	27
55°	63	24	4	45	7	59	53	46
50°	81	41	20	45	29	29	83	83
$\propto$ 45°	97	45	25	47	22	10	60	62
40°	92	29	20	44	24	11	34	80
35°	77	43	19	50	24	142	49	71
30°	87	26	21	51	17	15	14	32
$\propto$ S1	123	49	23	79	54	134	56	78

$\propto$ training stimuli (45° = S2 in all cases)

APPENDIX IV

EXPERIMENT 4:-

Baseline training data:

mean number of responses per minute for the final six sessions of baseline training (MULT VI-60sec VI-60sec) in both components.

Subject	S1 Stimulus	S1 Responses/minute
C1	blank key	48
C2	45° line	40
C3	blank key	61
C4	45° line	22
C5	blank key	40
C6	45° line	66
C7	45° line	63
C8	blank key	50

Subject	S2 Stimulus	S2 Responses/minute
C1	45° line	54
C2	blank key	42
C3	45° line	65
C4	blank key	21
C5	45° line	42
C6	blank key	67
C7	blank key	64
C8	45° line	50

Experiment 4: Generalization test data

Responses/minute

(1) Pre and post-discrimination training generalization tests in extinction:

(a) line orientation generalization tests:

i. Pre-discrimination training

	Subject							
Test Stimulus	C1	C2	C3	C4	C5	C6	C7	C8
0°	53	45	53	31	47	55	71	60
15°	63	48	55	26	58	60	72	49
30°	60	50	54	25	55	70	76	61
α 45°	64	45	59	25	55	52	62	54
60°	54	45	61	21	45	62	72	54
75°	56	48	50	34	51	59	74	55
90°	51	45	43	27	52	60	74	50
$^{\alpha\beta}B$	49	46	61	24	44	65	75	53

ii. Post-discrimination training

0°	35	51	143	17	17	34	52
15°	30	50	108	24	1	37	62
30°	22	64	78	36	1	51	87
α 45°	19	74	54	37	0	75	106
60°	24	61	98	30	0	49	96
75°	28	56	129	22	9	31	75
90°	37	43	133	19	8	36	60
$^{\alpha\beta}B$	85	0	130	2	82	7	40

α: the two training stimuli

β: B denotes blank key

(b) brightness generalization test:

Test Stimulus no.	Subject C1	C2	C3	C4	C5	C6	C7	C8
1	69	4	129	8	65	0	38	46
2	69	0	139	4	66	0	31	49
3	73	0	140	4	89	9	38	56
∝ 4 (=B)	85	5	157	15	77	0	41	58
5	52	49	103	22	73	39	74	55
6	48	68	86	24	55	53	77	53
7	0	93	21	37	11	47	89	0
∝ 45° line	14	59	51	28	30	57	68	7

(2) Resistance to reinforcement tests:

(a) line orientation

Test Stimulus	SESSION ONE C1	C3	C5	C8	SESSION TWO C1	C3	C5	C8
0°	62	145	67	60	75	133	54	77
15°	57	127	44	50	69	135	69	72
30°	52	110	33	43	81	124	48	68
α 45°	58	69	26	33	86	130	48	55
60°	49	97	30	45	75	123	32	63
75°	54	109	71	53	75	122	44	85
90°	68	119	114	58	69	133	39	75
${}^{\alpha\beta}B$	86	144	126	73	80	142	52	49

Test Stimulus	SESSION THREE C1	C3	C5	C8	SESSION FOUR C1	C3	C5	C8
0°	95	130	46	78	82	128	44	52
15°	90	149	33	61	88	115	74	70
30°	87	136	24	76	95	109	102	84
α 45°	78	141	50	86	103	107	108	89
60°	81	141	25	76	90	104	95	84
75°	64	123	34	74	85	115	48	82
90°	72	121	20	67	77	120	50	45
${}^{\alpha\beta}B$	71	148	98	60	79	156	67	46

(b) brightness dimension

	SESSION ONE				SESSION TWO			
Test Stimulus	C2	C4	C6	C7	C2	C4	C6	C7
No. 1	1	12	17	46	0	16	39	66
2	0	18	17	46	0	20	35	62
3	0	11	20	42	0	16	56	46
∝ 4	1	21	25	56	0	16	61	76
5	55	30	44	85	56	17	60	74
6	57	40	58	77	60	30	71	69
7	68	47	49	71	69	40	40	84
∝ 45^{o}	63	38	70	86	56	33	71	88

	SESSION THREE				SESSION FOUR			
Test Stimulus	C2	C4	C6	C7	C2	C4	C6	C7
1	2	24	46	83	0	24	63	69
2	0	26	65	89	1	17	50	63
3	0	17	49	71	0	31	47	82
∝ 4	1	22	73	72	25	15	61	95
5	39	27	64	69	43	19	57	89
6	53	22	58	83	50	29	60	72
7	51	36	49	79	45	27	54	84
∝ 45^{o}	53	34	66	90	83	30	67	60

APPENDIX V

EXPERIMENT 5:-

Baseline training data:

mean number of responses per minute for the final six sessions of baseline training (MULT VI-60sec VI-60sec) in both components.

Subject	S1 Stimulus	S1 Responses/minute
D1	blank key	61
D2	45^{o} line	89
D3	45^{o} line	28
D4	45^{o} line	63
D5	blank key	25
D6	45^{o} line	91
D7	blank key	36
D8	blank key	31

Subject	S2 Stimulus	S2 Responses/minute
D1	45^{o} line	64
D2	blank key	90
D3	blank key	30
D4	blank key	66
D5	45^{o} line	27
D6	blank key	95
D7	45^{o} line	35
D8	45^{o} line	32

Experiment 5: Generalization test data

Responses/minute

(1) Generalization tests in extinction

(a) line orientation tests

i. Pre-discrimination training

Test Stimulus	D1	D2	D3	D4	D5	D6	D7	D8
0^{o}	61	88	34	62	26	95	34	36
15^{o}	63	90	33	64	24	96	31	44
30^{o}	60	97	39	66	28	101	29	31
α 45^{o}	62	89	31	63	27	91	35	31
60^{o}	65	90	36	60	24	102	28	35
75^{o}	53	81	38	63	31	97	31	41
90^{o}	67	97	36	63	26	87	31	36
${}^{\alpha\beta}B$	61	92	30	66	25	94	36	31

(Subject: D1–D8)

ii. Post-discrimination training

Test Stimulus	D1	D2	D3	D4	D5	D6	D7	D8
0^{o}	59	69	7	82	32	89	50	29
15^{o}	62	83	17	99	21	103	23	22
30^{o}	61	131	24	105	18	146	29	19
α 45^{o}	32	136	24	111	18	149	17	14
60^{o}	52	126	22	104	17	136	17	15
75^{o}	63	90	20	102	24	103	22	15
90^{o}	62	62	10	72	36	92	33	24
${}^{\alpha\beta}B$	80	65	2	80	58	77	59	76

(b) brightness dimension: post-discrimination training

	Subject							
Test Stimulus	D1	D2	D3	D4	D5	D6	D7	D8
No. 1	2	90	4	29	32	107	6	8
2	5	90	9	46	44	101	16	11
3	9	81	11	56	46	97	28	19
∝β 4(=B)	25	86	20	70	50	100	39	33
5	50	84	21	71	52	98	66	60
6	78	62	11	80	67	78	76	76
7	31	82	22	70	47	105	61	54
∝ 45° line	34	137	48	108	18	149	15	11

∝ training stimuli

β B denotes blank key (70 lux)

(2) Resistance to reinforcement tests

- all are on the dimension of line orientation

(a) Around S2 (45^{o} line)

	SESSION ONE				SESSION TWO			
Test Stimulus	D1	D5	D7	D8	D1	D5	D7	D8
0^{o}	81	74	22	19	116	116	46	16
15^{o}	91	89	26	27	128	107	40	17
30^{o}	73	66	16	18	123	89	40	23
$\propto$ 45^{o}	86	60	19	19	117	98	30	31
60^{o}	73	45	19	17	117	82	45	30
75^{o}	91	61	12	25	181	105	46	28
90^{o}	101	72	39	36	129	107	52	17
$\propto\beta_B$	132	112	125	106	134	146	126	86

	SESSION THREE				SESSION FOUR			
Test Stimulus	D1	D5	D7	D8	D1	D5	D7	D8
0^{o}	131	81	111	41	141	71	143	57
15^{o}	130	96	109	45	120	88	130	61
30^{o}	107	102	95	64	138	87	110	75
$\propto$ 45^{o}	105	103	87	68	123	99	109	91
60^{o}	136	98	82	54	117	88	117	83
75^{o}	139	88	88	50	138	86	129	83
90^{o}	143	70	110	35	129	68	148	52
$\propto\beta_B$	134	88	148	61	149	103	193	97

(b) Around S1 (45^{o} line)

Test Stimulus	SESSION ONE D2	D3	D4	D6	SESSION TWO D2	D3	D4	D6
0^{o}	66	30	101	131	104	28	80	52
15^{o}	107	11	88	137	109	20	115	64
30^{o}	107	29	52	134	124	27	102	108
$\propto$ 45^{o}	114	21	93	146	118	21	89	98
60^{o}	57	11	83	108	109	29	92	96
75^{o}	113	35	88	145	80	24	100	113
90^{o}	41	16	84	100	30	43	92	93
$^{\propto\beta}B$	85	3	89	47	101	2	100	45

SESSION THREE

Test Stimulus	D2	D3	D4	D6
0^{o}	110	27	90	66
15^{o}	96	29	113	91
30^{o}	110	28	90	86
$\propto$ 45^{o}	131	33	115	114
60^{o}	105	33	100	112
75^{o}	107	29	85	115
90^{o}	42	25	115	68
$^{\propto\beta}B$	109	1	105	45

$\propto$ training stimuli

β B denotes blank key (70 lux)

APPENDIX VI

EXPERIMENT 6:-

Discrimination training data:

mean number of responses per minute for the final six sessions of discrimination training in both components S1 and S2.

Discrimination training	Subject	S1 Response Rate	S2 Response Rate
MULT VI-60sec EXT	E1	79	6
MULT VI-60sec EXT	E2	108	0
MULT VI-60sec EXT	E3	87	6
MULT VI-60sec EXT	E4	81	6
MULT VI-60sec VI-60sec(SIG)	E5	30	2
MULT VI-60sec VI-60sec(SIG)	E6	66	17
MULT VI-60sec VI-60sec(SIG)	E7	55	24
MULT VI-60sec VI-60sec(SIG)	E8	39	7

Experiment 6: Generalization test data

Responses/minute

1. (a) Generalization test in extinction

	Subject							
Test Stimulus	E1	E2	E3	E4	E5	E6	E7	E8
0°	63	9	26	14	16	29	25	12
15°	34	1	25	5	2	38	26	24
30°	10	1	12	0	5	40	16	36
$\propto 45^{\circ}$	17	0	2	1	2	35	30	15
60°	19	0	5	7	3	29	21	23
75°	34	1	21	9	3	45	27	8
90°	42	1	40	11	2	41	29	24
$^{\propto\beta}B$	88	146	101	99	29	68	88	40

(b) Generalization test in extinction: with added houselight

0° + houselight	38	6	11	20	25	31	25	19
15° " "	24	0	6	17	12	16	25	18
30° " "	8	0	6	8	21	49	32	29
$\propto 45^{\circ}$ " "	0	0	4	4	11	32	6	22
60° " "	2	0	6	16	21	11	8	12
75° " "	6	3	5	14	9	27	15	16
90^{0} " "	6	1	5	21	18	19	16	8
$^{\propto\beta}B$ " "	33	13	101	81	30	64	37	36

2. Resistance to reinforcement tests

- all are around S2 (45^o line)

SESSION ONE

Test Stimulus	E1	E2	E3	E4	E5	E6	E7	E8
0^o	31	6	66	59	25	62	67	32
15^o	26	3	67	57	18	61	67	23
30^o	8	0	0	0	3	43	45	12
$\propto$ 45^o	16	0	59	48	15	73	65	18
60^o	25	4	15	50	18	61	42	26
75^o	8	0	40	48	15	61	42	16
90^o	33	0	0	0	9	57	63	20
$^{\propto\beta}B$	101	157	89	65	23	92	90	52

SESSION TWO

Test Stimulus	E1	E2	E3	E4	E5	E6	E7	E8
0^o	70	3	65	55	17	48	54	39
15^o	7	0	8	24	7	42	38	13
30^o	57	3	91	67	17	58	41	25
$\propto$ 45^o	15	0	26	47	0	38	36	25
60^o	22	0	28	55	1	42	53	17
75^o	5	0	38	24	12	42	45	18
90^o	48	0	64	40	12	41	41	21
$^{\propto\beta}B$	96	112	93	76	27	99	64	39

SESSION THREE

Test Stimulus	E1	E2	E3	E4	E5	E6	E7	E8
0°	90	38	104	57	9	71	74	49
15°	91	67	86	61	10	58	56	30
30°	92	1	58	65	9	60	58	42
$\propto 45^{\circ}$	84	58	85	54	10	63	40	27
60°	88	39	74	46	6	64	62	21
75°	81	0	64	65	7	76	50	29
90°	99	1	69	83	13	53	57	27
$^{\propto\beta}B$	106	122	116	64	42	87	77	35

SESSION FOUR

Test Stimulus	E1	E2	E3	E4	E5	E6	E7	E8
0°	87	98	88	49	18	59	69	36
15°	78	48	61	60	3	36	58	24
30°	78	103	62	54	9	61	66	28
$\propto 45^{\circ}$	59	9	63	26	4	43	41	11
60°	48	22	60	40	5	40	51	24
75°	24	47	89	22	6	54	67	28
90°	91	78	69	35	16	48	46	15
$^{\propto\beta}B$	97	143	100	65	42	96	52	31

SESSION FIVE

Test Stimulus	E1	E2	E3	E4	E5	E6	E7	E8
0°	98	87	95	63	13	80	0	22
15°	85	19	84	36	9	78	56	22
30°	42	114	78	37	0	70	9	26
$\propto$ 45°	80	110	74	37	17	69	57	17
60°	76	91	51	39	8	57	73	31
75°	78	80	61	51	4	58	12	20
90°	91	86	75	58	1	66	0	14
$^{\propto\beta}B$	104	143	76	49	39	82	62	50

SESSION SIX

Test Stimulus	E1	E2	E3	E4	E5	E6	E7	E8
0°	106	118	81	*-	31	58	59	46
15°	26	110	64	25	17	58	56	29
30°	109	76	84	33	22	68	57	24
$\propto$ 45°	10	61	62	52	7	43	15	13
60°	62	85	76	36	3	48	0	21
75°	100	40	67	41	14	59	19	31
90°	103	79	65	26	17	48	62	19
$^{\propto\beta}B$	112	93	86	51	28	83	57	43

$\propto$ = training stimuli

β = B denotes blank key (70 lux)

* = key light inoperative